AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXIV.

(Vol. VII.—November, December, 1878.)

AMERICAN ENGINEERING,

AS ILLUSTRATED BY THIS SOCIETY AT

THE PARIS EXPOSITION OF 1878.

COMPILED BY

GEORGE S. MORISON EDWARD P. NORTH
JOHN BOGART

A COMMITTEE APPOINTED BY THE SOCIETY TO PREPARE THE EXHIBIT.

Presented with the Report of the Committee at the Annual Meeting, November 6th, 1878, and ordered printed as part of the regular Transactions.

CONTENTS.

ILLUSTRATIONS.

The Committee appointed by the American Society of Civil Engineers, to prepare an exhibition of American engineering at the Paris Exposition of 1878, has collected the matter contained in the following pages for the use of Members of the Society, and of the profession abroad. In these pages will be found special descriptions of many of the engineering works which have been illustrated at Paris, and also general articles upon different branches of engineering, these articles being intended to show the distinctive features of American practice in the departments which they cover, and at the same time to serve as introductions to the more detailed descriptions which follow, and to render these pages of more permanent value than would belong to a mere descriptive catalogue. For most of these articles the Committee is indebted to other Members of the Society.

The Committee states with regret that many of its requests for models and drawings to be exhibited, as well as for descriptive matter to be embraced in this report, have apparently miscarried, and hence some American works which it was hoped to illustrate were necessarily omitted, and some of the most valuable subjects exhibited are now inadequately described.

REPORT

OF THE INTERNATIONAL JURY OF THE PARIS EXHIBITION OF 1878, ON THE EXHIBIT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

SOCIÉTÉ AMÉRICAINE DES INGÉNIEURS CIVILS A NEW-YORK.

Nature des Produits Exposés.

Dessins et Photographies des grands ouvrages récemment construits ou en cours de construction aux États-Unis sur les voies de communications.

Observations.

La Société Américaine des Ingénieurs Civils a exposé collectivement les dessins et photographies d'un très grand nombre des ouvrages d'art les plus remarquables exécutés en Amérique dans ces dernières années, ou qui sont en cours d'exécution. Ces ouvrages comprennent des fondations de ponts, suivant divers systèmes, et notamment à l'air comprimé ; des barrages, écluses à plan incliné, ponts tournants, ponts et grands viaducs métalliques, ponts suspendus, dragues à vapeur, etc., etc.

Ces travaux, et particulièrement les viaducs métalliques et ponts suspendus, présentent une étonnante hardiesse de conception, une grande simplicité de forme, une extrême légèreté et une parfaite entente de l'emploi du fer et de la fonte pour atteindre le maximum de résistance avec le minimum de métal utilisé.

Le jury frappé de l'esprit continu d'initiative et de progrès que révèlent les œuvres exposées par la Société Américaine des Ingénieurs Civils, demande qu'il lui soit délivré une récompense exceptionnelle. Il regrette que le caractère de collectivité ne permette pas de décerner à chacun des ingénieurs dont les œuvres sont exposées, les médailles qu'ils méritent.

MEMBRES

de la Sous-Commission de la Classe '66 (Matériel et Procédés du Génie Civil, des Travaux Publics et de L'Architecture.)

FRANCE.

A. Bailly, *Architecte, Membre de l'Institut—President.*

Fredéric Ponsin, *Ancient Ingenieur de la Compagnie d'Orleans—Secretaire.*

Mozet, *Entrepreneur des Travaux Publics, et Juge au Tribunal de Commerce de la Seine.*

C. **Boutillier**, *Ingenieur des Ponts et Chaussées, Professeur a l'école Centrale des Arts et Manufactures.*

PAYS-BAS,

J. A. A. Waldorp, *Ingenieur en Chef des Ponts et Chaussées.*

ESPAGNE,

Carlos M. de Castro, *President du Comite Consultatif des Ponts et Chaussées et Phares d'Espagne.*

ETATS-UNIS D'AMERIQUE,

William Watson, Dr. Phil., *Membre de l'Academie Americaine des Arts et Sciences.*

[Translation.]

AMERICAN SOCIETY OF CIVIL ENGINEERS. NEW YORK.

Nature of Exhibit.

Designs and Photographs of great works recently constructed, or in course of construction in the United States, upon lines of communication.

Observations.

The American Society of Civil Engineers has exhibited, collectively, designs and photographs of a very large number of the most remarkable works of art, lately executed in America, or which are in course of construction.

These works comprise foundations for bridges of different systems, and notably by that of compressed air; dams, lockages on inclined planes, pivot draw bridges, bridges and great viaducts of metal, suspension bridges, steam dredges, etc., etc.

These works, and in particular the metal viaducts and suspension bridges, present astonishing boldness of conception, great simplicity of form, extreme lightness and thorough understanding of the use of iron and its working to attain a maximum resistance with a minimum of metal utilized.

The jury, impressed by the continued spirit of initiation and progress shown by the works exhibited by the American Society of Civil Engineers, request that an exceptional prize may be awarded. The jury regrets that the collective character of the exhibit prevents the award, to each one of the engineers whose works are represented, of the medals which they merit.

INTRODUCTORY.

The objects of the American Society of Civil Engineers are, the advancement of the science of engineering, the professional improvement of its members, and the cultivation of professional and social intercourse among engineers at home and abroad.

The Society has been organized a little over a quarter of a century; but it remained comparatively dormant until about ten years ago, when it was resuscitated, and started with fresh life and vigor upon a more active course; within that brief period it has achieved a prominent place among American Scientific associations.

The title of the Society would, perhaps, seems to designate it as exclusively devoted to *Civil* Engineering, and while this, in its more common acceptance betokens the calling of many of the members, it is expressly provided by its Constitution that the term shall have its wider significance; in fact among the members are Military, Mining, Mechanical and Gas Engineers; it also has numbers of fellows and associates, who are not specially attached to any of these professions, but who feel an interest in practical scientific pursuits.

The underlying principles which must govern all engineering works and all mechanical arrangements, are the same everywhere; but the climatal, social and commercial differences of countries have led to diverse architectural and engineering structures, adapted to the peculiar characteristics of each country.

Conspicuous among the modern appliances calculated to strengthen human brotherhood, and to benefit the race, are the world's expositions,

wherein are gathered the choicest productions of each country; placed side by side, conveniently arranged for satisfactory examination and comparison. London, Paris, Vienna and Philadelphia, representative cities of great countries, have in turn held these grand World's Fairs, and each succeeding international exposition has brought together, not merely the varied productions of different countries, but also their representative men in the most prominent industrial professions. Different portions of the globe have thus been brought face to face with each other in friendly competition. Especially in engineering, by means of models, photographs and description, much can be seen and learned by those who have not time or opportunity to visit different countries where works have been constructed. At the Philadelphia exposition, European, Canadian and South American engineers, as well as some from more remote parts of the globe, were, through the instrumentality of the American Society of Civil Engineers and the Institution of Mining Engineers, made, at least, partially acquainted with American engineering. These organizations heartily co-operated, and contributed, as far as they were able, to show to their foreign and American visitors some portion of what had been accomplished by American engineers.

Engineering, in most of its modern aspects, is young in the United States.

A country which in a single century has grown from a population of three millions, dwelling in thirteen weak colonies, to a population of forty millions, occupying thirty-eight powerful States, constitutes of itself a novel feature in the world's history; and no careful student can doubt that the rapid settlement and extraordinary growth, physically and intellectually, of the American States is now exerting a wholesome reflex action throughout the civilized world. The people of the United States are the united descendants of almost every European nationality. They have spread over a territory of more than three millions of square miles, embracing almost every variety of climate and production. With two great ocean fronts; with the grandest navigable

rivers and lakes, and the richest and most extensive valleys, on the globe ; a great field was opened for the work of the engineer.

The American growth of engineering partook of the new soil, the new climate and the new circumstances by which it was surrounded. In the early part of its history as a nation, the United States had no engineering school. With only weak credit, and mainly dependent upon the mother countries, it now seems surprising how early the spirit of enterprise in the people led to important works of internal improvement. In 1825, the Erie Canal, of the State of New York, three hundred and sixty miles in length, connecting the great chain of lakes with tide water on the Hudson river, was opened. Some minor canals had previously been completed, and some small improvements had been made in a few rivers and harbors ; but there was no national system. States, and individuals under State acts of incorporation, raised the means and conducted the operations. Two years later, in 1827, the railroad system, then just born in England, was started in the United States ; it has now ramified into every State and into nearly every Territory of the Union, and embraces over ninety thousand miles of commercial railroads.

The inaguration and the energetic prosecution of this vast system of public improvements, over an immense territory, much of it sparsely inhabited, extensive regions being settled only as the railroad track advanced, created a peculiar American railroad engineering profession, adapted to the novel circumstances. The American railroad engineer, of half a century back, with the birth of the railroad system, was obliged to construct his formulæ and his works simultaneously, and, in accordance with his financial basis, which was generally very weak. The American railroad capitalist was a thing unborn, as he had to be an outgrowth of the advancing system. American science was young. The present gigantic railroad system, which has cost four thousand millions of dollars, was not dreamed of. The great rivers, the stupendous mountains, the broad, rolling plains, the grand old forests, and the magnificent valleys, were here, in their pristine majesty, and their

subjugation by man, hitherto deemed to be the work of centuries, was, by the magic of American engineering, accomplished in fifty years.

The early American engineers have nearly all departed from the stage ; but the present world should credit them with having achieved great things with comparatively small means. Their children now occupy the improved fields which their fathers won from rude nature, and the civil engineering of America has changed ; scientific engineering has succeeded to the purely practical, and a single branch may engage the lifetime of a professional engineer.

FOUNDATIONS.

Foundation Work, as practised in America, like most other constructive features of public works, has been subject to limitations and requirements unknown to European countries. In America time is always pressing, distances are magnificent, and investment capital limited and urgent for speedy returns. In earlier days scientifically educated Americans were few, and engineers were largely ignorant of the precedent of foreign practice. Their main reliance was on their "home" experience, and that peculiar faculty of adapting ones self to circumstances, that almost all mechanics in a new country possess in a greater or less degree. Work, to be done at all, had to be done cheaply, expeditiously, for capital could not afford to remain passive, and effectively, to avoid future losses and repairs. Had the fathers of American engineering been men of greater education or scientific culture, they doubtless would have been far less successful in their works, and fewer enterprises would have been undertaken. Strongly self-reliant, those men of the earlier days of American engineering accepted fully the requirements of a new country, and set to work to solve the problems appertaining thereto.

In the matter of foundations, these men availed themselves, almost from the beginning, of the great abundance of cheap timber for their works, and time has proved the wisdom of their course and the excellence of their judgment. In fact the free use of timber may be regarded as the chief difference between American and European methods of founding masonry in deep water, or river crossings. Many of the most important railroad bridges have their piers founded on timber cribs filled in with stone, the timber work being carried up to within a couple of feet of lowest water mark before starting the masonry. On bottoms subject to erosion, a plentiful supply of rip-rap is dumped around the founda-

tion, and replenished from season to season until well solidified. This is the most common system employed throughout Pennsylvania and New York, and in fact in all States where the character of the river bottoms is of such a nature that a solid bearing on rock, hard pan, or gravel, can be insured. Where a soft material overlies a hard bottom, loose stone is thrown in, which soon forms a solid bearing for the crib work, or the crib is built tight with square timbers, with an open bottom, sunk by temporary loading, the soft material—mud, sand, or silt, as the case may be—sucked out by pumps or dredged out, as may best apply to the circumstances, the void then being filled in with concrete or broken stone. In case of a rough or sloping bottom, the lower courses of the crib are made to conform to it as nearly as possible, from previously determined soundings. Many of the cribs used are of round logs, notched at their intersections and secured with long drift bolts. For bottoms ill adapted to crib work, the most usual practice is to drive piles, the area of the foundation having been previously dredged below scour, if possible. The piles are cut off truly level by means of a horizontal saw on a vertical shaft, or the simple device of a pendulum saw, and as close to the bottom as possible. The interstices between the piles are leveled up with stone. On the bottoms so prepared a crib is sunk, economising the masonry up to near low water mark, or a timber caisson is floated over the piles, the bottom of which forms the platform for the masonry, which is carried up in the usual way as in the open air. To control the flotation, a valve is sometimes provided in the caisson, through which water may be admitted to be pumped out again as occasion requires. The sides of the caisson are detachable, and are used again, should there be more than one pier to found. A modification of the former method has been practised by depending on the *piles* for the immediate bearing of the platform, and using a timber crib as a protecting envelope surrounding them, all voids being filled up with stone or concrete. In this case the piles, of course, are cut off at the distance below low water that it is desired to commence the masonry. In all cases where there is any possible chance of scour, it is usual to protect the area surrounding such foundations by means of rip-rap.

Exceptional works often require expensive methods; but even such works, in this country, are of very recent dates. The application of the pneumatic system, so long practised in Europe, to the foundations of the East River and the St. Louis bridges, are examples familiar to the

profession, having been detailed at length in the printed reports of their respective engineers. They are probably the most extended examples of the system extant, and required great boldness and constructive skill to carry out. Two notable improvements were developed in the construction of the St. Louis bridge piers, viz.: the use of the water column for driving out the sand through pipes, and the placing of the air lock at the bottom of the well, leaving the long ascent and descent of the workmen to be accomplished in the ordinary atmosphere. The common European practice of using iron cylinders with the pneumatic system, has been applied in this country to but few bridges, of which that at Omaha is the most extreme example. The Poughkeepsie bridge, now building, has its enormous piers founded on huge square-timbered cribs, sunk by dredging through the wells formed by the cross walls of the cribbing, to a depth of 110 feet and over; the crib work being filled with concrete forms a solid base for the masonry commenced 25 feet below low water, and towering 135 feet into the air above high water mark. This is the boldest example of timber foundation work on record, and perhaps meets the most extreme case of deep water foundation that the engineering needs of the country will ever call for.

Out of the persistent demand for accomplishing results cheaply and rapidly, grew what American engineers know as the Cushing System, which consists of square timber piles driven to their full bearing in intimate contact with each other, forming a solid mass of bearing timber. Surrounding the pile cluster so driven is an envelope of cast or wrought-iron, sunk sufficiently in the mud or silt simply to *protect* the piles, all voids between piles and cylinders being then filled with hydraulic concrete. The piles alone support the load. Several such foundations have been used, and answer an admirable purpose. Time alone will tell whether the only objection that can be used against the system, viz.: "dry-rot" has any foundation in fact.

The water jet has been used economically and with good results for sinking piles in soft bottoms, notably in the case of Tensas bridge in Alabama, where iron cylinders were put down by simply directing through gas-pipe a system of jets driven by an ordinary steam pump.

The preceding description fairly covers the leading features of foundation methods practiced in this country—except, perhaps, coffer-dams of which no mention has been made. As a rule, coffer-dams are

avoided, excepting in comparatively shallow waters, and where there is some reasonable certainty of getting a tight bottom. The uncertainty of what future trouble and expense a coffer-dam will develop before the bottom is laid bare, causes engineers to select some one of the several methods previously outlined. A novel floating coffer-dam has been built in New York, that has been experimentally successful in laying dry a mud bottom, but no work has thus far been laid with it; it is simply a long rectangular double walled caisson with an inside court as it were, having sheet piling sliding in guides in the inner wall of the caisson, which when driven down into the mud or clay (it is only practicable on a homogeneous mud or clay bottom) acts as ordinary sheet piling. The caisson is sunk by filling its walls with water, and is rigged with steam pumps for exposing the bottom, and clearing the caisson of its water ballast. The ends of the caisson are movable, permitting of its removal as a whole from the completed work.

Screw piles, so largely used abroad, have been used but little by American engineers.

Looking to the future, it is not probable that demands will be made upon the skill of American engineers for much more difficult foundation work than has already been accomplished, and it may be many years before projects arise which will match those already executed in this class of constructions. But be that as it may, American foundation work will long be characterized by a free use of timber in the form of cribs, caissons, platforms and piles, and a very limited use of iron, pneumatic processes or coffer-dam work, in which particular as was remarked in the commencement, lies the distinguishing characteristic between American and European systems of foundation.

SUBJECTS EXHIBITED.

1. *Two photographs of masonry bridges on the Lake Shore & Michigan Southern Railway, selected from a lot of photographs sent to the Society by* Mrs. Charles Collins.

2. *Photographs showing the towers of the East River Bridge in process of construction.* W. A. Roebling, Chief Engineer.

The East River Bridge consists of a central suspended span of 1 595′ 6″ length between centres of towers, and two side spans, also suspended, each 930 feet long.

The approaches increase the total length to about one and one-sixth miles.

The ends of the cables are anchored in two masses, containing a total of 26 000 cubic yards of masonry. These masses are each about 119 feet by 132 feet in plan at the base, and about 89 feet high, and are founded on a grillage of timber from 4 to 7 feet thick, which rests directly on sand; the timber being below the level of water in the soil, and consequently not subject to decay.

The piers at either side of the river rise to a height of 271½ feet above mean high tide. At high water surface the extreme measurements were in plan, 57′×141′ in Brooklyn, 59′×141′ in New York.

In Brooklyn the foundation rests mostly on boulder clay, but a sufficiently uniform foundation was not found until a depth of 44½ feet below tide was reached. To obtain this depth a timber caisson was sunk, having exterior dimensions of 102′×168′, and a height of 24½ feet. Both caissons when launched were 15 feet high, and additional timber to the heights named was put on after launching. The air chamber, which was afterwards filled with concrete, had a height of 9½ feet. The final pressure at bottom of foundation will be about 5½ tons per square foot. The pressure on top of the timber is 9¼ tons per square foot. The total quantity of masonry, including concrete, 43 900 cubic yards.

The New York pier rests on compact sand and gravel, immediately overlying the bed rock. The caisson was 102×172×31½ feet, also of timber. The edge of the caisson is 78 feet below tide. The tower contains about 55 000 yards of masonry and concrete. The pressure at the base is about 6¾ tons, and on top of the timber about 10½ tons per square foot.

Work on the Brooklyn caisson was begun November 1st, 1869. The caisson was launched in March, 1870, and put in place, and the first

stone set June 15th, 1870. It was sunk to full depth and filled in by March, 1871. Stone work of the pier completed December 1st, 1874.

The New York caisson was begun September 6th, 1870; launched May 8th, 1871; put in place and sunk to depth, May 17th, 1872; filled with concrete, July 22, 1872. First stone of pier set, October 31, 1871, and pier finished July 15th, 1876.

Last wire of cable laid, October 5th, 1878.

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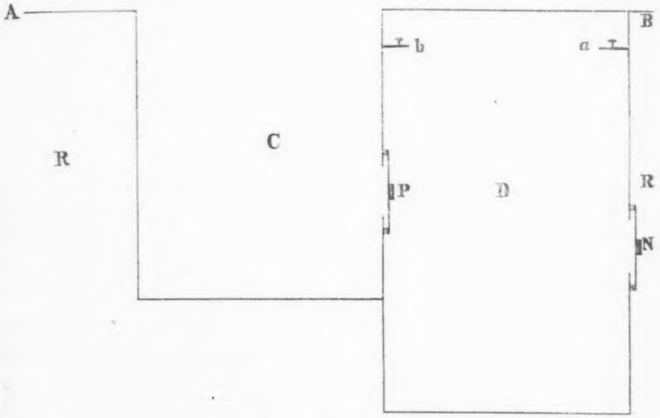
3 *and* 4. *Detail drawing and photograph of the foundation works of the East pier of the St. Louis Bridge.* James B. Eads, Chief Engineer.

All the great piers of this bridge, four in number, stand upon the bed rock of the river. Two of them are nearly two hundred feet high. The base of the West abutment was laid within a coffer-dam; the other three were sunk through the water and river sand by the method of compressed air. The method employed was in many of its features entirely new, and in nearly all important respects the work was on a scale far surpassing all previous experience. The most difficult, on account of the depth and strength of the river and the distance to the rock, was the East pier, and it was undertaken first. The iron caisson enclosing the air chamber was first towed into position between the large guide piles. Its length was 82 feet, its width 60 feet, and the depth of the chamber was 9 feet. The ceiling of the chamber was stiffened by cross plate girders, and the walls by iron knee braces. Two walls of oak timber running the entire length of the caisson helped to support the ceiling as soon as the caisson reached the bottom of the river. These walls, as well as the outer walls of the caisson were built with a broad flat base which took a bearing on the sand.

In all cases the masonry was laid in the open air, beginning on the roof of the caisson. Powerful air pumps supplied air at a pressure sufficient to expel all water from the air chamber. The masonry of the East Pier was protected from the water by a coffer-dam of iron plates riveted to the edges of the caisson, and the descent of the caisson was to a certain extent regulated by suspension bolts and nuts. The iron coffer-dam around the masonry was, with the exception of a few courses required while the caisson was still floating, omitted from the West Pier as a costly and unnecessary feature, while the East Abutment was sunk in the most satisfactory manner, without either the coffer-dam or the suspension rods.

Entrance to the chamber was through air locks, the main one being in the center, as shown in the drawing. The method of entrance and exit is easily seen from the diagram.

A B is a portion of the ceiling of the caisson. *C* is a cylindrical well sunk into the air chamber and open above. *D* is the air lock placed wholly within the air chamber, and connecting by the close fitting door *P* with the well *C*, and by a similar door *N* with the air chamber *R R*.



The door *N* being shut and *P* open, the men descend into the well *C* and step through the opening at *P* into the air lock. One closes the door *P* while another admits the compressed air from the chamber by means of the cock *a*. When the air ceases to enter, the door *N* swings open. Exit is made by reversing the order and allowing the compressed air of the lock to escape at *b*. In the East Pier, ascent to the top of the masonry was by means of stairs. When the caisson was on the rock, the stairway was fully one hundred feet high. The stairs were supplemented in the East Abutment by an elevator, to the great relief of the workmen.

The East Pier was sunk from the surface of the river to the bed rock in 134 days, the East Abutment in 132 days. The sand was removed by sand pumps, the general arrangement of which consisted of a water jet discharging upward through the centre of a hollow globe; this globe was placed in the caisson at the bottom of an iron tube which extended upwards through the masonry and was connected with a flexible tube below; the lower end of the flexible tube was kept submerged in the water below the level of the bottom of the caisson and this water was drawn upwards by the inducing force of the jet, carrying with it a large quan-

tity of sand; the general arrangement was not unlike that of the Giffard injector. The sinking was mainly regulated by undermining the bearings. In the East Abutment, which is probably the most successfully constructed deep foundation ever built, the process of "settling" was reduced to a science. The discharge of the sand pumps was in excess of the masonry, though as much as 346 cubic yards were laid in less than twelve hours on that one pier. Whenever the height of the masonry required that the pier should sink, the air pumps were stopped, and the air was allowed to escape slowly from the chamber. The motion of the water along the outer faces of the masonry and caisson, and under the cutting edges rendered the sand sufficiently mobile to produce a gentle and perfectly regulated descent of the caisson and its huge burden; workmen meanwhile undermining the central walls. The starting of the air pumps would instantly stop the settling.

The caisson of the East Abutment was built of wood, with only a single thickness of iron plates to make it air-tight. The wood consisted of squared oak timbers bonded and strongly bolted. The timber surfaces were whitewashed, and the air chamber was brilliantly lighted by lamps burning in glass globes fed by compressed air, and discharging the products of combustion into the upper air through tubes.

When the bed rock was reached it was cleared of all loose material, and concrete was packed under all the supporting surfaces. The air chambers of the channel piers were filled solid with concrete. This was mixed on the top of the masonry, and introduced through small air locks, and being done at the maximum depth, was a work of great difficulty, involving no small danger to the workmen. The caisson of the East Abutment was filled with sand, except under the walls which rest on concrete. The caisson was allowed to fill with water and the sand was then pumped in, and required no packing except a few inches under the roof, where it was rammed as firmly as possible. The base of the East Abutment is 83 feet by 70 feet 6 inches; the top is 64 feet 3 inches by 47 feet 6 inches. The height of the masonry is 192 feet 9 inches. It contains 22 453 cubic yards of masonry, and its weight, with half the span it supports, is about 46 500 tons. Its base is 134 feet 6 inches below high water.

The caisson of the East Pier cost $111 000; that of the East Abutment, $139 700. The masonry and sinking of the East Pier cost about $469 000; that of the East Abutment $451 000.

Twelve men who worked under the East Pier died from the effects of compressed air. One only died at the East Abutment, and he suffered the penalty of positive disobedience of orders. Excepting this unfortunate loss of life, no serious accident attended the construction of these massive foundations.

5. *Detail Drawing of the foundation work of Pier No. 5 of the St. Charles Bridge over the Missouri River.* C. SHALER SMITH, C. E.

This bridge crosses the Missouri River at a point 17 miles west of St. Louis, and 20 miles above the junction of the Mississippi and Missouri Rivers. Being within the range of the Mississippi backwater, the variation of the water level at this point is over 40 feet, and the flood speed of the current very great, exceeding in fact 9½ miles per hour twice, during the period occupied in the construction of the bridge. In 1869, after the piles had been driven for the breakwater for Pier No. 5, a heavy freshet occurred, which carried away the works at this point, and in doing so, scoured out a large hole at the pier site, which hole was soon filled with the traveling boulders which move along the bed of this river at such times. After the subsidence of the flood, a careful examination showed that the proposed site was occupied by an inverted pyramid of boulders and drift wood, 200 feet long by 70 feet wide at the base and about 22 feet thick at the deepest part. The caisson, which was of iron, double-walled and cellular, had already been arranged for sinking with the water jet and Ead's sand pump, and was altered to suit the new condition of the case, as follows :

An air lock 12 feet high, was placed at the foot of the down-stream shaft, the upper side of the lock being a large door, which swung vertically, was nearly the full section of the shaft, and was counterweighted so that the strength of one man sufficed to raise it into place. The underside of the air lock was seven feet below the top of the air chamber, and the up and down stream sides were provided with large doors 36 inches by 30 inches, placed as close to the floor of the lock as possible. The air was admitted to or from this boulder lock in less than one minute, through an inch and three-quarters pipe, the stop cocks of which were managed by a man within the air chamber and outside the air lock, as this rapidity of alteration of pressure was too great for human life to endure.

This arrangement was found to work admirably. Small iron cars 24 inches by 18 inches by 36 inches were filled with boulders, and run on skids into the lock, the air was let out, the upper door dropped down, and the fall tackle of a large derrick passed down the shaft, was hitched to the car, and the latter was then drawn out, swung around, and its contents emptied on to a barge, where they were broken up into concreted stone, for use in the hearting of the pier. Many of the boulders weighed from 600 to 1 300 pounds each, and were too large for the cars. These were passed on trucks into the boulder lock, and were taken out in slings by the derrick. After 3 feet in depth of boulders had been removed, the sand which had formed the matrix, generally made a layer of about 12 to 16 inches in depth. This was removed by the Eads

sand pumps, the suction pipes of which reached to all parts of the air chamber.

The most economical method of working was found to be as follows: While excavating, the air was kept at a pressure of from 10 to 15 feet (or 4½ to 6½ lbs. per inch) greater than required by the depth at which the men were working. This dried the bed for two feet below the cutting edge. The boulders were excavated until water was reached, and under the bearing beams were replaced by sand, well tamped; the sand layer was then pumped out and the pressure in the air chamber lowered until the pier sank down to the top of the boulders. A marked feature of this foundation was the great friction of the materials after the boulders had commenced caving and packing. In the last 20 feet the pier never moved until a skin friction of 466 lbs. per square foot of immersed surface had been overcome.

Eads sand pumps removed 18 cubic yards of sand per hour each. They were found to work best with a three-inch discharge pipe and 200 lbs. per square inch water pressure. Three Cameron pumps, with 12″ × 24″ steam, 6″ × 24″ water cylinders were used to supply two of the sand pumps, and were worked up to their full capacity in so doing.

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6. *Detail Drawing of the foundation work of the Poughkeepsie Bridge* P. P. Dickinson, Chief Engineer.

(See Plate XXXIX.)

This work is located at Poughkeepsie, on the Hudson, 75 miles north of New York city. The width of the river at the bridge site is 2 430 feet, and the depth of water from 50 to 60 feet, with a tidal motion of three miles per hour. The bed is composed of 20 feet of sediment and mud, 10 to 40 feet of compact blue clay, 6 to 10 feet of sand, and 10 to 15 feet of coarse gravel, with boulders overlying the rock, which is at a depth of from 119 to 145 feet. There are to be five spans, of 525 feet each, with a depth of truss of 65 feet. The substructure consists of four river and two shore piers, with two abutments, to be built of granite masonry to a height of 135 feet above high tide, having a base of 72 by 32 feet, at 20 feet below high tide, and 40 by 12 feet at top—giving a pressure at the base of about 5 tons to the square foot. The shore piers and abutments have their foundations on rock, on the river bank.

The four river piers are founded on caissons, filled with concrete and resting on the bed gravel—the East pier being 122 feet, the two central 112 feet, and the West pier 97 feet below low tide. The caissons are 60 feet wide by 100 feet long, composed of yellow pine and white hemlock timber, 12 inches square. The lower edge of the ends, sides, and central portions of the caissons is built up solid with timber thoroughly bolted together, for a height of 18 feet, running from a cutting edge, shod with iron to a thickness of 10 feet on the sides and ends and 15 feet

in the centre wedge-shaped portion. Transverse walls of timber, commencing 4 feet above the cutting edges, bind the caissons together, dividing the central portion into 12 open compartments. At the height of 16 feet, the transverse and the exterior longitudinal walls are 3 feet thick, and the four interior longitudinal walls 2 feet thick. By this plan of building, the caisson is divided into 40 compartments. The outside and centre line of compartments are 28 in number, placed over the cutting edges. These compartments receive the concrete required for additional weight in the sinking. The remaining 12 compartments, each 12 feet square, extend to the bed of the river, and through them the material is removed by aid of the Clam Shell dredge ; the sinking of the caisson being controlled by excavating from either of the 12 compartments until finally resting in position.

A notable feature of the work is the great depths from which material has to be dredged, and the ease with which the caisson is held in position. The extreme depth of dredging required is one hundred and thirty feet, which is being done without difficulty. The work of sinking the caisson to its foundation having been completed, the services of a diver are availed of, who makes an examination of the river bed through the various open compartments, and upon whose report of the removal of all unctuous materials the work of filling in with concrete begins. It is lowered to the river's bed by the use of the clam-shell dredge, where it is deposited in masses of four to five yards at a time, without damage from wash, forming an artificial base homogeneous with the bed gravel. This filling continues to the top of the caisson, a height of seventy-seven feet in the case of Pier No. 4, now completed, the same being twenty feet below low tide, at which point the granite work begins. The caissons contain each an average of two and a half millions of feet, board measure, of timber, and three hundred and fifty tons of wrought iron, and will contain forty columns of concrete, twelve of which, twelve feet square, extend from the bed gravel to within twenty feet of low tide, the remaining twenty-eight resting upon the cutting edges which are solidly imbedded in the gravel and extend to the same height. The concrete is composed of Portland and Rosendale cement, mixed with sand, gravel and broken stone, in the proportion of five to one.

The examinations and soundings of the river at Poughkeepsie, for the purposes of determining the feasibility of obtaining suitable and safe foundations, were made in 1872, and carried forward to a full and satisfactory development of the entire practicability of the undertaking. On the 20th of January, 1875, a contract was entered into by the Poughkeepsie Bridge Company with the American Bridge Company of Chicago, Illinois, for the completion of the work. New soundings and examinations of the river were made by the latter company at the proposed sites of the different piers, fully confirming those of 1872 and 1873. The

great depths to which it was found necessary to go to reach the gravel, upon which the foundations rest, required a plan by which the dedesired object could be secured without resort to the pneumatic process, which has been accomplished by adopting the present plan of open caisson designed by W. G. Cooledge. By the terms of the contract between the Poughkeepsie Bridge Company and the American Bridge Company the bridge is to be completed and ready for the passage of trains by January 1st, 1881. It is being constructed under the immediate direction of P. P. Dickinson, Chief Engineer of the Poughkeepsie Bridge Company, and W. G. Cooledge, Engineer of the American Bridge Company.

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6. *Models of iron pier and caisson foundations, as constructed at Omaha, Leavenworth, Booneville, Fall River, &c. Loaned to the Society by the American Bridge Company.*

BRIDGE SUPERSTRUCTURE.

(See Plate XL.)

The early American bridge builders built almost entirely of wood; they found timber abundant, cheap and good, iron was scarce and dear, and the limited amount of capital forbade the construction of masonry arches where any cheaper substitutes, even of a temporary character, could be used. They built wooden trusses to cross rivers and wooden trestles over ravines; the former to be renewed from time to time, as the timber decayed, the latter ultimately to be filled with earth embankments.

While the earlier truss bridges were of experimental character and of many different designs, two forms soon took a prominent place as the most common and probably the best wooden bridges; these were known as the Burr bridge and the Towne lattice. The Burr bridge was built of square timber; the chords were made of two timbers placed side by side; vertical pieces were placed about ten feet apart and framed through the chords, projecting sufficiently, above and below, to form a connection which would resist tension, and diagonal struts were framed into these verticals between the chords. The Towne lattice was built entirely of plank, usually three or four inches thick, all the connections being made by wooden pins driven through auger holes, the arrangement of parts being generally similar to those of an iron lattice. Both of these bridges did good service, and they are still used for highway bridges in rural districts. They were usually completely covered in, and frequently strengthened by timber arches springing from the masonry several feet

below the trusses, to which they were fastened at frequent intervals. Good examples of these bridges, built as early as the beginning of the century, are still standing.

Another wooden bridge of somewhat later date, but which was built very largely about twenty years ago, was the MaCallum truss. It was in reality a modification of the Burr, the peculiarities being in the upper chord, which was always curved so as to increase the depth of the truss at the centre, and in the use of the so-called arch braces, which starting from the masonry, passed through the lower chord and terminated at different panel points in the upper chord. It was the boast of the inventor that these braces would sustain the bridge even if the lower chord were cut in two, and an instance actually occurred in which the entire lower chord and floor fell under the weight of a train into the river, and the upper portions of the truss were left standing. This bridge was exceedingly stiff and for a time very popular, but it was so complicated that it was customary to make a full-sized drawing on a smooth floor, from which patterns were taken for the framers. It has now gone out of use.

The first real advance from the old wooden trusses was made about forty years ago, when iron rods were introduced to take the tensile strains of the web. This was accomplished in two different trusses, the Pratt truss, in which the web was composed of vertical timber compression members with diagonal rods for ties, and the Howe truss, in which the rods were vertical and the diagonals were wooden struts, one system of bracing being precisely the reverse of the other, and both furnishing the opportunity for perfect counter bracing, in which the Burr bridge was deficient, and which was a necessity in railroad bridges. At first the two systems appeared of equal merit, but the vertical rods of the Howe required a minimum amount of the more costly material, and afforded special advantages for simplicity of detail ; on the other hand, it was found difficult to keep the two iron diagonals of the Pratt truss in proper adjustment. The Howe soon took the place which it still holds, as the standard wooden truss, while it was left for the iron construction of a later period to appreciate the real merits of the Pratt.

The Howe truss may justly be termed the most perfect wooden bridge ever built ; others have been designed of greater theoretical economy ; but for simplicity of construction, rapidity of erection and general utility it stands without a rival. As usually built, the chords

are made up of three to five sticks of timber, 10 to 14 inches deep, and 6 to 8 inches wide. They are placed about an inch apart, the lengths breaking joints, and are fastened together at intervals of about 4 feet with iron bolts and wooden keys, the latter being blocks two inches thick, which are let into the timber half an inch; in the lower chords the joints in each line of timber are coupled with wooden clamps. On the chords (above the lower and below the upper) rest the cast iron angle blocks; these are castings as long as the chord is wide, and of triangular section, two surfaces serve as skewbacks for the diagonal braces to rest upon, and the third surface, which comes against the chord, has a lip cast upon it which, fitting into a groove cut across the chord, serves to transmit the strain from the block to the chord. The angle block is cast with two or more holes, through which pass the vertical rods; these are simply straight rods of round bar iron, with a screw cut on each end; they pass through the chords, between the different lines of timbers, and the nuts screw up against washer plates of wrought iron placed above and below the chords. The only framing about the braces is to cut them square to length, and the entire truss can be laid out with a square and scratch-awl, and framed with no other tools than a saw, an adze, and an auger. When once properly erected, the only attention required is an occasional adjustment of the nuts so as to preserve an equal strain in the rods of each set.

Mr. Howe built his first bridge, a single highway span of 75 feet in 1840; his second bridge was a railroad bridge of seven spans of 180 feet each across the Connecticut river at Springfield, built in the same year. The lower chord was made of planks packed close together with oak tre-nails; the panels were only seven feet long and the braces reached across two panels; the braces were all of the same size as were also the vertical rods; the angle blocks were of wood. This bridge, though light and badly proportioned, lasted till 1853, when it was replaced by a Howe truss of more modern design, which was still in fair condition in 1874 when it was replaced by a double-track wrought-iron structure.

The Howe and Pratt trusses as originally built were empirical structures like their predecessors; they were proportioned by imperfect rules and without calculation. The simplicity of their design, however, offered inducements for analysis, and the analytical methods now used by American engineers in building iron bridges were applied by the best builders to these more crude structures.

The Howe and Pratt trusses introduced the use of iron for the lightest portions of the truss ; the next advance was to make the entire truss of iron. The general plans of the wooden bridges were adhered to as far as they were applicable to the new material ; the bottom chords, strained in tension, were made of wrought iron bars, and the compression members were of cast iron. The bars of the lower chord were joined together with eyes and pins, and the upper chord was cast in panel lengths with square bearings ; the rods of the web usually passed around the pins of the lower chord, while the connection at the upper end was by nut and screw. The first successful iron bridges were those designed by Squire Whipple, many of the earliest of which are still standing, their skeleton being substantially the same as that still in most common use ; a Pratt truss with the end posts inclined so as to reach over the first panel.

The adjustable truss with cast iron compression members was the real beginning of iron bridge building in America. A large number of bridges of this sort have been built even to a late period by Mr. Francis C. Lowthorp, in which all tensile connections are made with screws.

Up to the year 1850 few iron bridges had, however, been constructed of longer spans than fifty feet.

The first impulse to the general adoption of iron for railroad bridges was given by Mr. Benj. H. Latrobe, Chief Engineer of the Baltimore and Ohio Railroad. When the extension of this road from Cumberland to Wheeling was begun he decided to use this material in all the new bridges. Mr. Latrobe had previously much experience in the construction of wooden bridges in which iron was extensively used ; he had also designed and used the fish-bellied girder, constructed of cast and wrought iron, and which is still in use on the Baltimore and Ohio Railroad ; he had adopted on the older portion of that road the Bollman plan of bridge for short spans, which has since come into extensive use. But for the general plan of bridges west of Cumberland he adopted the plans submitted by Mr. Albert Fink, his assistant.

The basis of this system was the trussed girder, the straight beam with a single post at the centre, supported by inclined rods reaching to each end. Mr. Fink increased the practical length of this style of truss by making each half a secondary trussed girder, and then by treating the quarters and subsequently the eighths in the same way, he extended the single principle of the trussed girder to a truss of sixteen panels ;

the same upper chord acted as the beam for all the systems, but otherwise they were independent.

In both the Fink and Bollman trusses all parts were suspended from the upper chord, and no lower chord was required; they were distinguished by the name of *suspension* trusses. One of the earliest examples of the Fink truss is the bridge over the Monongahela River on the Baltimore and Ohio Railroad, completed in 1853, and still in use. The chords and posts were of cast iron, and the tension members of wrought iron. The bridge consists of three spans, each of 205 feet length, the longest then constructed in this country. All the bridges on the Baltimore and Ohio Railroad were built upon this general plan, and it was adopted on many roads in the South. In many bridges wood was substituted for the cast iron in the parts which resist compression, and this combination resulted in a structure which combined durability with great cheapness. It may be proper to mention here that this plan of truss was particularly designed with the view of making it self-adjustable, when two materials are combined in it, which are differently affected by change in temperature.

While this development in the construction of iron bridges was going on quietly in the more Southern States, during the years from 1850 to 1860, very few iron bridges were then built in the Northern States. The reason for this delay in the adoption of iron for bridge construction must be found in the general prejudice which then existed in the mind of the public, shared even by many engineers, which had been caused by the failure of a badly proportioned iron bridge on the New York and Erie Railway in 1850, and also by the failure of the iron bridge over the River Dee, in England, which took place about the same time. It was difficult for the few engineers, who combatted the Crystallization Theory which was then advanced, to overcome this prejudice. It was some ten years after the commencement of the earlier efforts to which reference has just been made that iron bridges were introduced on the Pennsylvania Railroad, upon the plans of Mr. J. H. Linville. The best of these earlier examples is the bridge over the Ohio river, at Steubenville, which was built in 1862, with a span of 320 feet.

About the year 1867, iron bridge building in America began to assume its present importance. In this year the first iron bridges over the Mississippi were begun, and the scheme for the great bridge at St. Louis began to assume a definite form. At this time the most prominent

designs for iron bridges were of four kinds. The Fink and Bollman suspension trusses, the Pratt truss and the Warren girder. The Howe truss had been built in iron to a limited extent, but it was soon found that however excellent in wood it was poorly adapted to iron construction. In order to obtain greater economy in the web without the use of panels of unusual length, the Pratt truss was built with a double web system (called the Whipple, Murphy, or sometimes the Linville truss), and the Warren girder was either doubled or the floor was suspended by vertical rods from the intersections of the braces with the upper chord. Cast iron was generally used for compression members which were cast of hollow cylindrical form. Mr. Linville, President of the Keystone Bridge Company, had, however, built bridges with wrought iron posts, and the hollow wrought iron riveted column made by the Phœnix Iron Company, had already been received with much favor. Many builders, however, preferred to retain the cast iron top chord, while using the wrought iron posts in the web.

Shortly before this Mr. S. S. Post had designed and patented the Post truss. The details of this bridge were in many respects novel, but the distinctive feature was the arrangement of the posts and ties of the web; the bridge being usually built with a double web system, and the posts being given an inclination across half a panel, main ties across a panel and a half, and the counter ties the same inclination as the posts reversed. This design was the result of careful calculations, and thought to be very economical..

About this time, also, the use of combination bridges became common—this term being applied to bridges in which the lower chord and other tensile members were of wrought iron, the top chord and compression members being wood. The origin of this system of construction may, perhaps, be found in the early suspension trusses of Mr. Fink, with wooden chords and posts. Mr. Fink also introduced what was known as the V combination truss, a Warren girder with top chord and braces of wood and lower chord and ties of wrought iron; this bridge was easily protected from decay by covering the upper chord and principal braces with a tinned roof; it is, probably, the best combination bridge built, and is used largely in many parts of the South, where it has virtually superseded the Howe truss, The Post truss was often built as a combination truss, and the Pratt truss is still built in this way. The first bridge across the Missouri river, built in 1867–69, at Kansas City, by

Mr. Chanute, was an example of a combination double system Warren girder, with curved upper chord.

The introduction of wrought iron posts was soon followed by the use of the same material in the heavy compression sections of the top chord, and the best builders were not slow to realize that the screw adjustments which were important in wooden bridges were of no advantage in an iron structure; the screw connections at the upper ends of the tension rods were accordingly dispensed with, and bridges built with pin connections throughout. The use of cast iron has gradually become less and less, until now many engineers have entirely dispensed with it, making all the connections and details entirely of wrought iron.

The peculiarities of American iron bridges, as compared with those of the European builders, may be traced in no small measure to the fact, that in America the construction of wooden bridges was practically perfected before the building of iron bridges was begun, Many of the features of wooden construction were repeated in iron, sometimes with very unsatisfactory results, and only to be abandoned as the builders became more proficient; but the most prominent feature of American bridge design is the concentration of the material in a few members, and this was realized in the Pratt, Howe and other trusses, before iron bridges were built. Simplicity of skeleton form has been followed from the first; and since the use of wrought iron track stringers has removed the objections to long panels, single systems of bracing have generally been preferred to double, and the simple Pratt truss, of wrought iron with inclined end posts, and all tensile connections made with eye bars and pins, has of late years been built more largely than any other design.

The European systems, on the other hand, have not been without their advocates; riveted structures, copied originally from foreign designs, were early introduced on the New York Central Railroad and some of its connections, and this has ever since been the standard system of construction on those lines. The earlier bridges were generally built with vertical compression members and inclined ties; the latter being so numerous as to give the structure the appearance of a lattice bridge. For the shortest spans riveted plate girders were used. This system of construction has not been without its influence on the designs which are considered more strictly American, and its development has undoubtedly been modified by the standards of other builders.

Plate girders and trellis bridges, built of plates and angle-irons, have now become the favorite forms of iron construction for spans of 60 feet and under, and their use is yearly becoming more common. On the other hand, in trusses of greater length, the builders of riveted work have departed from the European forms of construction and concentrated their material in comparatively few members, the usual design being a species of lattice in which the parts are so few that each diagonal is intersected by only three others—the truss being, in fact, a four-system Warren girder, in designing which the strains of each member are separately calculated in much the same way as is done in the more widely separated members of a pin-jointed truss. One of the best examples of riveted bridges was built in 1874, over the Connecticut river, at Sprinfigeld, Mass., on the piers once occupied by the first Howe truss that ever carried a railroad.

In the early building of railroads and even of late years in the construction of lines in timbered or thinly settled districts, the use of wooden trestle work played a part hardly inferior in importance to that of wooden truss bridges. The plan of trestle work commonly adopted consisted of bents placed from 12 to 18 feet apart, each bent consisting of a sill, four posts and a cap, all of timber 12 inches square; the sill rested on piles or sub-sills according to nature of the foundation; the two inside posts were vertical and placed directly under the rails, and the outside posts were given a batter of about 1 in 4; the posts were framed into the sill and plate with mortise and tenon, and the bent was stiffened by diagonal planks bolted or spiked on each side. Stringers resting on the caps connected the several bents, and on them were laid the ties to which the rails were spiked. This trestle with very slight modifications has been built in all parts of the country, and used to carry railroads across ravines where the cost of earth embankments was too great for the economical demands made on the engineeer. Where the height exceeded about 30 feet the bents were built in two or more stories, an intermediate cap with light longitudinal stringers being placed at the top of each story. For structures of great magnitude special designs were followed, in the best of which the use of mortise and tenon was abandoned, and the different lengths of timber were made with square butt-joints resting directly upon one another. The best known example of this class of structure was the great Portage viaduct designed by Mr. Silas Seymour in 1851, which was so arranged that every

timber could be taken out and replaced without disturbing the stability of the structure.

The first examples of iron trestles were erected in 1853 by Mr. Fink on the Baltimore & Ohio Railroad. There are two of these trestles or viaducts, crossing ravines on Cheat River at an elevation of 250 feet above that river. They are located on grades of 1 in 50, and one of them on a curve of 800 feet radius, and are built entirely of cast iron. The trestle is sixty feet high—the posts are cast in two sections; the lower has a diameter of 7 inches, and the upper of 6½ inches, with ¾-inch thickness of metal. Every 25 feet there is a vertical post, from the foot of which two inclined braces start; the braces in the several panels meet at the top in the centre of the twenty five feet space, giving a support to the stringers bearing the track, every 12½ feet. The length of these trestles is 500 feet, and they are built in sections of 125 feet length; each section is braced together in such a manner as to permit it to slide—from the centre each way—upon the foundation plates, in order to permit of the contraction and extension of the structure under the influence of changes in temperature.

These structures, presenting an extremely light appearance, have now been in use for twenty-five years, and may, perhaps, be considered the boldest attempt in the use of cast iron in bridge construction.

About a dozen years ago Mr. C. Shaler Smith began building wrought-iron trestles, using Phœnix riveted columns for posts, each bent consisting of two posts with cross struts at intervals of about 30 feet and diagonal tie rods, the bents being placed 30 feet apart, supporting trussed girders, and stiffened longitudinally by struts and diagonal ties; these trestles were built at first with all longitudinal members of wood so as to avoid any difficulties from thermal expansion, but by omitting the struts in every third or fourth span, there was found no difficulty in making all parts of iron. This general system of construction has now become very common, and iron viaducts of skeleton design are built by all bridge builders, the designs being more or less varied to suit the peculiar requirements of each case. In all of these, however, the same prevailing characteristic is found that marks the truss bridges, the concentration of material in a few members, and the economical advantages of this system are found even greater in lofty viaducts than in long span trusses. The most remarkable example of iron viaducts is the bridge lately built by Mr.

Smith across the Kentucky river, consisting of three spans each 375 feet long, which rest upon iron towers, and carry a railroad at a height of 275 feet above the river.

As early as 1847 Squire Whipple printed with his own hands a memoir on the strains in skeleton structures, in which the general principles of calculating strains, and proportioning the parts of the more common forms of trusses were correctly enunciated. This memoir was the foundation of American scientific bridge building. The practice of American bridge builders is to calculate in detail the strains on each separate member of a truss, preparing strain sheets or skeleton diagrams, on each line in which the estimated maximum strains are marked; in common practice railroad bridges are designed to carry 3 000 pounds for each foot of track with an additional allowance to cover the extreme strains produced by a heavy locomotive on the floor and web systems; it is not unusual, however, to calculate the effects of an actual train, considering the different weights on the wheels. The pin joint system offers the best assurance that the actual strains will agree with the calculations, and renders simple the connection of large sized members, whose use in riveted structures is virtually excluded by the large number of rivets required in the joints.

The practice has been to build the several members of a bridge in the shop, finishing every part. The tensile members are eye-bars with forged heads and eyes drilled to fit accurately on turned pins; the compression members are usually built of plates, angles and channel irons, or of special shapes like the sections of the Phœnix column. Each member is complete as it leaves the shop, and the bridge has only to be put together at its site, little or no riveting being done there; a span of ordinary length will be erected in two or three days.

The last ten years have witnessed the erection of structures of a magnitude which had not been attempted in America till then. The Raritan draw bridge which turns on a central pier and has a total length of 472 feet, and the channel span of the new bridge over the Ohio at Cincinnati, 520 feet long, both designed by Mr. Linville and built by the Keystone Bridge Company; the Rock Island draw bridge, designed by Mr. C. Shaler Smith, and weighing 750 tons; besides the draw bridges, all over 360 feet long, on the Mississippi, and four other bridges across the Ohio with channel spans from 350 to 400 feet, are examples of the application of the more usual forms of construction of

works of unusual size. The St. Louis bridge with its three spans of steel-ribbed arches each about 500 feet long; the stiffened suspension bridge at Pittsburg, and the great steel wire suspension bridge at New York with a clear span of 1600 feet, the cables of which are now in position, are prominent cases in which the engineers have thought best to depart from the usual forms of truss construction and to erect structures specially designed to meet the peculiar requirements of each case.

SUBJECTS EXHIBITED.

7. *Photographs of the old and new viaducts at Portage, New York, and detail drawings of the new viaduct.* Silas Seymour, Engineer of old viaduct. Geo. S. Morison, Engineer of new viaduct.

(See Plate XLI.)

The original Portage bridge was the most remarkable timber viaduct ever erected. It was begun July 1st, 1851, and completed, so as to cross with an engine, on August 14th, 1852. The viaduct was over 800 feet long and 234 feet high from bed of the river to the rail, the masonry being 30 feet high, the trestles 190 and the trusses 14 feet. It contained 1 602 000 feet B. M. of timber, 108 862 lbs. of iron in bolts, and 9 200 cubic yards of masonry. Three trestles were grouped together forming a timber pier, and it was estimated that a single one of these piers would sustain 3 000 tons besides the weight of the structure. These piers were fifty feet apart. The general plan was made by Silas Seymour, Chief Engineer, and the drawings and bills of material prepared by H. C. Brundage.

On Thursday, May 6th, 1875, this timber viaduct was destroyed by fire. The destruction of everything above the masonry was complete.

On Monday, May 10th, the contract for the iron work was let to the Watson Manufacturing Company, of Paterson, the bridge to be built according to plans of George S. Morison, C. E. The first iron column was raised June 13th. On July 29th the iron was all in position; on the following day the track was laid across, and on Saturday July 31st, the bridge was tested and thrown open for traffic.

The main principle of the plan may be said to be that which characterizes all American bridge building, and is the leading difference between the works of American and European engineers; the concentration of the material into the least possible number of parts.

The iron viaduct has 10 spans of 50 feet, two of 100 feet, and one of 118 feet, a 50 feet span being placed between each of the long spans. The trusses

are supported by wrought iron columns, the ends of two adjacent trusses resting upon a single column. The pair of columns supporting the opposite trusses are in the same vertical plane, but are inclined towards each other and connected with wrought iron struts 25 feet apart and diagonal tie rods, thus forming a two post bent; each column is connected with the parallel column of the adjoining bent by a similar arrangement of struts and diagonal ties; four columns with the connecting bracing are thus made to form a skeleton tower, 20 feet wide and 50 feet long on the top, surmounted by a fifty feet span of bridge, having the same length at the bottom and a width varying with the height of the tower. There are six of these towers, the largest having a total height from masonry to rail of 203 feet 8 inches.

The trusses of the superstructure are proportioned to carry a moving load of 3 000 pounds per running foot, and an excessive load of 5 000 pounds per foot, with a maximum tensile strain of 10 000 pounds per square inch. The towers are built to carry a moving load of 5 400 pounds per running foot (being designed for two tracks); they are also calculated to resist a wind pressure at right angle to the bridge, of 30 pounds per square foot, exerted on the entire surface of the structure and of a train of cars, and one of 50 pounds per square foot exerted on the surface of the structure alone.

The columns rest upon cast iron pedestals, those on the North side of the bridge being secured by dowels to a cast iron plate sunk in the masonry, and those on the South side being placed on rollers, rolling at right angles to the axis of the bridge. The columns are made in 25 feet lengths. They are formed of three plates and four angle irons, with a lacing on the fourth side, so that the interior of the column is accessible for painting. The angles are all $4 \times 4 \times \frac{1}{2}$ inches, and the plates are all 16 inches wide; the thickness of the side plates being varied to provide for the increased strains in the lower sections. The ends of the several lengths are squared and faced, and they rest directly upon one another without joint boxes; the upper end of each length is fitted with two projecting plates which form a tenon; the length above fits over the tenon plates and is secured to the lower length by a turned pin of $1\frac{3}{8}$ inch diameter passing through carefully bored holes; this same pin serves for the attachment of the longitudinal rods. A second pin at right angle to this one forms the attachment for the transverse strut and ties. The diagonal ties are everywhere in pairs. The longitudinal strut, which is nearly fifty feet long, is built in the form of a light lattice truss, is two feet deep and one foot wide, with the ends squared and butting against the side of the column.

The towers were raised with no other falsework than that actually used in handling the material of each successive section. Before beginning to raise a tower, a floor of long timbers reaching from pier to pier and loose boards was laid at the site of the tower; on this floor was

erected a frame work 30 feet high, and composed of two bents, one on each side of the tower ; each bent consisted simply of two posts 48 feet apart and a cap 55 feet long, braced with planks across the corners. The lower lengths of the columns were then lifted into position; the transverse and longitudinal struts put in place and the diagonal ties put on. A gin pole 55 feet high was then lashed to each column, and these gin poles were used to transfer the floor and frame to the top of the now completed lower section of tower. The same operation was then repeated with the second lengths of columns, which were placed over the tenon plates of the lower length, and secured by the pins. When the second section of the tower was completed, the frame was used to raise the gin poles ; the floor and frame were then raised again, and the process repeated till the tower attained its full height. The last tower raised, weighing 277 000 pounds, was entirely erected in 11 days, one day only having been previously spent in preparing the staging for the first section.

To erect the long spans, combination Pratt trusses were built, the top chords of which were made of four pieces of pine 4 × 10 inches, packed in pairs, and sprung about 4 feet apart in the centre ; the bottom chord was of straight parallel eye bars and the posts V shaped ; the form of the top chord made the truss stiff without lateral bracing. These trusses were put together below, and raised by block and falls to the bottom of the upper section of the towers, where they were placed, resting upon the transverse struts, two being used for each span. A suitable staging was then erected on them, and the permanent truss was put together, the materials being run out from the end of the bridge.

The trusses are of the simple Pratt pattern. One end of each long truss is bolted to the iron capital of the column and the other is placed on rollers, but connected with the next truss by iron loops passing over the end pins of each span, and allowing only the amount of motion needed for expansion. The short spans over the truss are bolted to the capitals at both ends. The end pins of the 50 feet spans are placed 6 inches from the centre of the column, and those of the long spans only 3 inches, so that under a full load the centre of weight comes directly in the line of the centre of the column.

The total weight of iron in the bridge is 1 310 000 pounds, divided as follows :

Towers		897 550
10 spans 50 feet each	197 420	
2 " 100 " "	128 910	
1 " 118 "	86 120	
Total weight of superstructure		412 450
Total		1 310 000

The amount of timber in the floor, foot-ways and railing is 112 318 feet of oak and 18 300 feet of pine (B. M.), while 27 987 pounds of iron were used in bolts and washers, the heavier bolts being all bolts taken from the ruins of the old bridge.

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8. *Photographs of iron double track railroad bridge over the Delaware at Easton, and detail drawing of double track iron bridge on Erie Railway; built by* Messrs. KELLOGG & MAURICE.

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9. *Photograph of double track iron bridge at Corning, on the Erie Railway; built by* CHARLES MACDONALD, C. E.

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10. *A collection of bridges built by Delaware Bridge Co.* CHARLES MACDONALD, C. E. President.

(See Plate XLII.)

The group exhibited by the Delaware Bridge Co. comprises:

1st. A photograph of the Passaic Draw Bridge, near Newark, N. J.

2d. A photograph of the Oak Orchard Viaduct, on the Rome, Watertown and Ogdensburg Railroad, New York.

3d. A photograph of the Rockville Bridge, on the Pennsylvania Railroad, near Harrisburg, Pa.

4th. Drawings of some important details of the bridges illustrated by the above photographs.

PASSAIC DRAW BRIDGE.

This is a wrought iron double track structure, crossing the Passaic River at Newark, on the line of the Morris & Essex Railroad. There are three trusses, sustaining the tracks upon iron beams suspended from the lower chords.

General Dimensions.

Length of trusses from centre to centre of end pins ....220 ft. 6 in.
Height of trusses from centre to centre of chords................22 ft.
Width of bridge from centre to centre of outer trusses ....30 ft.
Height of rail above the water..................................45 ft.

Weights adopted for Calculation.

Dead load per lineal foot of bridge.......................... 2 000 lbs.
Live load, per lineal foot, covering both tracks throughout entire length.. 5 000 lbs.
Live load, per lineal foot, covering both tracks for one half the span.. 7 000 lbs.

When the bridge is open all the dead load is transmitted to the central support, and the strains are determined as in the case of a beam supported in the middle. When the bridge is shut and the wedges adjusted, the extremities are brought to rest only, and the strains due to dead load are not materially changed ; the effects produced by the rolling loads are now determined under the assumption that the bridge is supported at the centre and extremities ; and finally, the maximum strains are obtained by adding the strains due to fixed and rolling loads with their proper sign :

Weight of Iron in the Structure.

Upper chords	45 000	lbs.
Lower chords	52 000	"
Posts	65 780	"
Diagonal bars	48 800	"
Pins	5 900	"
Upper lateral system	15 800	"
Lower lateral system	4 800	"
Portals	2 600	"
Cross floor beams	68 970	"
Longitudinal floor beams	41 120	"
Weight of iron in trusses	350 770	lbs.
Weight of iron in turn-table	107 690	"
Total	458 460	lbs.

The trusses are of the "Whipple" type, with the end posts inclined, and with two inclined posts and a vertical at the central point of support. The chords are, for the most part, made up of two 10 inch channels and a cover plate on one side, with open lattice work on the other, forming a trough shaped section. In the centre panels of the upper chord, where tension alone exists, eye bars are used ; all other connections in the chords are designed to resist both tension and compression. The lower chords of the centre truss abut against a casting which forms the upper portion of the turn-table, and are secured to it by angle iron lugs. The lower chords and central posts of the outer trusses are riveted at their intersection to splice plates, making a continuous wrought iron connection. The connections at the abutment ends are also riveted. Vertical posts are made up of channels latticed on both sides, forming a rectangular section open on both sides to inspection. The ends are reinforced, and pin holes bored for connection with the chords. No joint boxes are used.

The dead weight of the bridge is transmitted to the revolving surface of the turn-table through the casting at the centre of the lower chord of the middle truss; that portion is borne by the middle truss directly, while the outer trusses rest upon the extremities of two plate girders connected

on each side the center by diaphragm plates and lugs; by this means the entire weight of the outer trusses and cross-girders may be suspended upon twelve vertical bolts passing through holes in the sides of the central casting. This casting rests upon conical steel rollers enclosed between steel rings grooved to fit the coning of the rolls, and having half an inch play between: upon these rollers the bridge revolves. The lower ring is fitted to a cast iron seat having a hemispherical cavity on the under side to receive a corresponding cast bearing block which distributes the weight upon a wrought iron pintle extending to the masonry. Under each end of the cross girders are four trailing wheels adjusted so as to bear lightly upon the track. When one line of rails is loaded, these wheels sustain a portion of the weight, but not when the bridge is turning.

Attached to the lower side of the base girders forming the ends of the bridge, are castings containing movable wedges having one and a half inches vertical play; they are beveled to fit bed castings attached to piers so that when they are driven to a bearing, horizontal displacement becomes impossible. The free ends of the track are lifted simultaneously with the wedge movement.

The bridge may be operated either by steam or by hand, as desired. A double cylinder engine drives a vertical shaft to which are attached two friction clutches. By throwing the upper one into gear a horizontal line of shafting is made to actuate the wedges and rail lifters. By shifting to the lower friction, motion is communicated to a driving pinion working into cast toothed segments which are bolted to the masonry through the track.

A vertical shaft, for working by hand, is placed between the rails; it communicates with the wedge gear by a chain wheel, and with the driving pinion by a small intermediate.

The time required to withdraw the wedges and swing the bridge does not exceed two minutes.

This structure was erected in place of an old wooden bridge, during the winter of 1876–77, and the traffic of the railroad was not seriously interrupted during the progress of the work.

Oak Orchard Viaduct.

A single track wrought iron structure on the line of the Rome, Watertown and Ogdensburg Railroad, near Rochester, New York.

General Dimensions.

Total length between abutments...............	690	feet.
Twenty-three spans, each....................	30	"
Height of trusses............................	9	"
Width of bridge, centre to centre of chords....	10	"
Height of rail above the water.................	80	"

Weights adopted for Calculation.

Dead load per lineal foot................	500 pounds.	
Rolling load consolidation engine in a length of 50 feet........................	150 000	"

Weight of Iron in the Structure.

One span of 30 feet	7 000 pounds.	
One bent 75 feet high....................	12 000	"
Total weight in the entire viaduct.......	365 000	"

In general type it resembles similar structures in other parts of the country, and is an economical distribution of material for crossing ravines. The principal bents are 75 feet in height from masonry to base of rail; they are framed in two lengths and spliced on the ground by riveting cover plates through the flanges of the channels. All the connections at these splices are of wrought iron. The main posts are made up of two 10-inch channels latticed at each flange and entirely open and accessible to painting and inspection. Base castings are anchored to the masonry to obviate the necessity of a horizontal strut at the foot of the bents. The 30-feet spans consist of plate girders 20 inches deep trussed by a centre post, and eye-bars. The tension transmitted through these bars is applied to the web of the girder at a point below the centre, with a view of counteracting the bending effect produced by the driving wheels of a locomotive on a half span. Changes due to temperature are provided for by firmly bracing each alternate pair of bents and connecting the 30-feet span between them with the caps of the posts, thus forming a horizontal strut and constituting with the two bents a rigid pier entirely independent of the rest of the structure. The 30-feet spans between each of these piers are attached to post caps by bolts passing through slotted holes, allowing ¾ inch play.

The time expended in the erection of the structure was three weeks. The iron was delivered at the bottom of the ravine and lifted into place by means of a movable projecting derrick.

Rockville Bridge.

A double track wrought iron structure crossing the Susquehanna River five miles above Harrisburg, Pa., on the line of the Pennsylvania Railroad.

General Dimensions.

Total length between abutments................	3 675 ft.
21 spans..	156 ft. 6½"
2 spans..	151 ft. 0½"
Height of trusses centre to centre of chords.......	19 ft. 7"
Number of trusses per span....................	3.
Width of bridge centre to centre of outer trusses	22 ft.
Height of rail above the water..................	45 ft.
Angle of skew...........	68°

Weights adopted for Calculation.

Dead load per lineal foot........................	2 750 lbs.
Rolling load per lineal foot......................	6 000 "

In the determination of maximum strain in the upper chords, it was assumed that the bending effect due to excess of locomotive weight was added to the direct compression.

Weight of iron used in the structure.

For one span of 156 feet 6½ inches.

Upper chords................................	100 790	pounds.
Lower chords................................	57 930	"
Vertical end posts..........................	8 770	"
Inclined posts..............................	45 290	"
Counter braced diagonals....................	12 670	"
Diagonal tension bars.......................	15 670	"
Sub-posts...................................	8 030	"
Pins and nuts...............................	6 750	"
Lateral struts..............................	15 030	"
Lateral rods................................	7 000	"
Lateral bolts and nuts......................	1 850	"
Wind bracing................................	5 400	"
Shoes at feet of end posts..................	2 450	"
Bed plates..................................	1 200	"
Expansion rollers...........................	670	"
Total iron in one span....	289 500	"
Total iron in the bridge...............	6 670 000	"

There are three trusses in each span, with the tracks so disposed upon them as to bring an equal distribution of load upon each.

The top chords are of 12 inch channels, with thickening plates, covers upon the top and the lower side latticed. The web consists of a double system of main post and tension bars, inclined at an angle of 45 degrees, and connected at their intersection midway between the chords, by pins. At their intersection with the chords they are also connected by pins, dividing the spans into eight main panels of 19 feet 6 inches each. From the middle intersection of the web members a vertical sub-post extends to the under side of the upper chord, forming a support for that member half way between the main panel points. The chord splice occurs at this point, and at each splice the ends abut squarely, and cover plates are riveted on to insure a continuous member. The braces are built of channels, latticed on two sides, forming a rectangular section, accessible to inspection on all sides; the ends are reinforced, and they are bored for upper, middle and lower pin connections. Where tension only occurs, eye-bars are used, instead of latticed channels. Bottom

chords are made of eye-bars, in panel lengths of 19 feet 6 inches, disposed both inside and without the jaws of the braces, so as to insure a uniform distribution of strain upon each eye-bar in a panel.

Lateral struts and rods are attached directly to the pins by U-shaped nuts, and a vertical bolt, no cast iron being used.

The rails are laid upon cross timbers, of oak, 7×14 inches, spaced 21 inches, centre to centre, and resting directly upon the top chords, which were proportioned to resist this extra bending strain.

This structure was built to replace a wooden bridge constructed upon the general type known as the Howe Truss. The terms of the contract required that the new bridge should be erected without interfering with the traffic of the railroad, or in any way endangering the stability of the old structure until the trains were transfered to the new; after that, the old material was to be taken apart and placed upon trains for removal. On the 24th of May, 1877, the Delaware Bridge Company signed a contract with the Pennsylvania Railroad Company, for furnishing the material, and the completion of the structure by the 1st of December of the same year. On the 11th of August the first span was in place; and on the 18th of November following, the last span was completed, and regular traffic began over the entire length of the new bridge. The erection began at the middle of the bridge, and was continued simultaneously, with but few delays, to the two extremities. Two movable derricks served to place the iron in position, and afterwards to take down and load the old material. During the progress of the work, the average number of trains passing over the bridge per day was sixty-four, and no interuption of traffic occurred,

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11. *Drawing of the Illinois and St. Louis Bridge.* JAMES B. EADS, Chief Engineer.

The supporting members of the superstructure consist of twenty-four steel arches, eight in each span. Each arch is composed of a large number of straight tubes, with slightly beveled ends, and to the casual observer appears to be a continuous curved tube. The arches are arranged in four ribs, each rib consisting of an upper and lower member connected by a system of wrought iron diagonal bracing. The axes of the upper and lower members form parallel curves twelve feet apart. Each span has four ribs. The whole number of tubes is 1 036. A tube is about twelve feet long, and comprises a steel envelope $\frac{1}{4}$ inch thick, and 6 rolled steel staves, varying in thickness from $2\frac{1}{8}$ inches at the springing to $1\frac{3}{16}$ inches at the crown. The exterior diameter is always 18 inches. Steel or wrought iron sleeve couplings firmly unite the tubes by means

of parallel grooves turned on the ends of the staves. Steel pins through the couplings and staves receive the ends of the main brace bars. Each main brace consists of two heavy rolled iron bars, about two feet apart, with T bars and lattice bracing between. The two lowest tubes of each member are screwed into heavy wrought iron skewbacks which rest on cast iron bed plates, and by long steel or iron bolts are anchored to the masonry. All these bolts are 5¾ inches in diameter, and from 22 to 36 feet in length. In the channel piers the bolts pass through the masonry and unite the two skewbacks. About 2 200 tons of steel and 3 400 tons of iron are used in the whole bridge.

The length of the West span is 504.07 feet, of the East span 504.84 feet, and the centre span 522.39 feet, measured on a line through the centers of the lower skewback pins.

The roadways of the bridge are carried by vertical struts made of braced iron channel bars resting directly upon both ends of the steel pins already mentioned. The upper roadway is 54 feet wide.

The bracing between adjacent ribs consists of tubular iron struts screwed to the ends of the steel pins, and diagonal steel tension rods. The diagonals are in horizontal and vertical systems. The vertical system serves to distribute live loads from rib to rib, and renders it possible by screwing up the ties to throw the entire weight of one rib upon the others, and take the rib to pieces; a tube injured during erection was taken out after the entire span had been completed, and a new tube was inserted. Each pair of ribs supports a railroad track. To increase the lateral stability a horizontal wind truss the full width of the bridge extends across each span immediately below the upper roadway. It is a lattice girder made wholly of iron. The chords of each truss are united at the piers and rest upon the channeled surface of a cast iron block which is fixed in position by large wrought iron bolts running to the right and left and deep into the solid masonry.

All the anchor bolts and sleeve couplings were tested; the steel bolts to 40 000 lbs. per square inch, the iron ones to 18 000 lbs. per square inch. A large proportion of the staves were subjected to an actual compression of from 50 000 to 60 000 lbs. per square inch. Specimen bars of all the material used were tested in great numbers and records kept. Over thirty model steel tubes and hundreds of steel cylinders from American and European manufacturers were tested in the investigations.

The public test of the bridge consisted in placing fourteen locomotives simultaneously upon the tracks of a single span.

The arches were erected by building the ribs out from the skew backs, partly self supported, but mainly held by iron cables passing over towers built on the tops of the piers. All the adjustments were made with the greatest accuracy, and the arches were all closed in the centers of the spans by the use of "extension" tubes capable of being lengthened or shortened by means of solid wrought iron cylinders filling the interior of

tubes and furnished with right and left handed screws. The contract of making and erecting the superstructure was taken by the Keystone Bridge Company of Pittsburg, Pennsylvania. Great difficulty was experienced in obtaining steel and iron of the required shape and strength, but in spite of every unforseen trouble, every part of the plan was faithfully executed.

In giving to the Chief Engineer, Capt. James B. Eads, the pre-eminent place as the designer and controlling spirit of the enterprise, we must not fail to mention the eminent services of his assistants, Col. Henry Flad and Mr. Charles Pfeifer.

The bridge was publicly opened on July 4, 1874. The cost of the bridge, including a large amount of interest and commission accounts, was not far from $10 000 000.

A full account of the Illinois and St. Louis bridge, by Professor C. M. Woodward, of St. Louis, is nearly ready for the press, from which the above account, as well as that of the foundations, has been taken. The work has been undertaken at the request of Capt. Eads, and all questions of fact will be endorsed by him. The history of the bridge will include the organization of the company, description of the work at all stages, difficulties met, preliminary tests, and tests of working pieces, process of erection, theory of the arch, and the calculations, It will be illustrated by fifty or sixty large plates and numerous small cuts.

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12. *Photographs of Girard Avenue Bridge, Philadelphia, designed by* Clarke, Reeves & Co.

(See Plate XLIII.)

There are seven lines of trusses or girders placed side by side 16 feet apart, and united by horizontal and vertical bracing.

These trusses are of the double Pratt system. The upper compressive members and the vertical posts are Phœnix flanged columns, united by cast-iron joint boxes. The lower chords and diagonals are weldless eye-bars, die forged by hydraulic pressure. Upon the top of the posts, 12 feet apart, are laid heavy 15-inch rolled beams, and upon these longitudinally, 9-inch beams placed 2 feet 8 inches apart; these are covered transversely with rolled corrugated plates ¼ inch thick, corrugated 1¼ inch high by 5 inches wide; these form an unbroken iron platform upon which the asphalte concrete is placed.

The dead load of the structure with a moving load of 100 pounds per square foot makes a total load of 30 000 pounds per lineal foot, carried by seven trusses.

The limit of strain is 10 000 pounds per square inch, reduced to 6 000 pounds per square inch as the compressive limit on parts. All points of contact are either planed or turned. The pins are of cold-rolled iron,

and the limit of error between pin and hole is one sixty-fourth of an inch.

The iron used in this bridge is double refined, capable of bearing the following tests : ultimate strength, 55 000 pounds to 60 000 pounds per square inch ; no permanent set under 27 000 pounds to 30 000 pounds per square inch ; average reduction of area at point of fracture 25 per cent, The elongation of a 12-inch bar is 15 per cent., and the cold bend of a 1½-inch round bar before cracking, 180°, or hammered flat.

The floor is made of corrugated iron plates covered by 4 inches to 5 inches of asphalt, making a water-tight surface. The 100 feet of width is divided into 67½ feet of carriage way, and two 16½ feet sidewalks. The roadway is paved with granite blocks in the usual manner, except that it is divided into seven ways by two lines of iron trackways next the sidewalks for horse cars, and five lines of carriage tramways, made of cut granite blocks 1 foot wide, laid to a 5-feet guage. The gutters and curb-stones are of fine cut granite. The sidewalks are covered for 10 feet of their width with black Lehigh County slate tiles, 2 feet square, laid diagonally. On each side of the tiles are spaces 2 feet wide, which were originally laid with encaustic tiles. After one winter's frost, these tiles became so much shattered that they were removed and white marble tiles substituted in their place. The curb-stone, 18 inches wide, makes up the remainder of the 16½ feet.

The sidewalks are separated from the roadway by railings of galvanized iron tubes with bronze ornaments, and are supported by cast-iron standards at every 6 feet. Every eighth standard is prolonged into a lamp-post. There are eight refuge bays, each of which contains a cluster of six lamps, the supporting shaft rising through an octagonal seat, which forms its base. The outer balustrade and cornice is of cast-iron with bronze open work panels, and treated in a highly ornamental manner.

The construction of the permanent new bridge began May 11th, 1873, and July 4th, 1874 it was formally opened for public travel.

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13. *Photographs of Ice in Delaware River, showing piers of bridges with superstructure gone, near Port Jervis, and of new iron bridge erected at same point.* George S. Morison, Engineer.

The bridge was destroyed at 7.40 A. M., March 17, 1875. It was a double track iron bridge of five spans, one through span over the Delaware and Hudson Canal, and four deck spans over the Delaware River. The span over the canal was undisturbed. The ice lifted the four river spans from the piers, leaving the masonry uninjured. The East span settled down on the ice, remaining within a few feet of its proper position ; the other three were carried down the river on the floating ice

and left at various points from four to twelve miles below. The West span was 160 feet long in the clear, the others each 150 feet, the rail being about 50 feet above the ordinary stage of water.

The work of reconstruction was begun at once, and a temporary bridge consisting of two spans of trestle and two of Howe truss was ready for use on Saturday, March 27th. The plan for a new permanent structure was determined on and proposals received, on the day of the disaster, and a contract was made with the Watson Manufacturing Company of Paterson, N. J., to build the new bridge by the pound. The plans were virtually completed and the bills of material were on the way to the rolling mills on the 18th.

The first span, 166 feet over all, was entirely shipped on Saturday, April 3d, and swung Wednesday, April 7th.

The second span, 156 feet over all, was swung Monday, April 12th.

The third span was swung Saturday, April 17th.

The fourth span was swung Monday, April 19th.

The permanent floor could not be put on till Sunday, April 25th, and on the following day the double track was completed, precisely 40 days after the destruction of the old bridge, the new iron bridge having been manufactured in 30 days, and erected in 32 days from the date of the contract.

The long span weighs 304 422 pounds, and the others averaged 265 641 pounds, making a total of 1 101 345 pounds, besides cast iron bed plates.

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14. *Photograph of Iron Railroad Bridge over the Ohio River, at Louisville, Ky.* ALBERT FINK, Chief Engineer. F. W. VAUGHAN, Assistant Engineer.

(See Plate XLIV.)

This bridge crosses the Ohio River at Louisville, connecting the States of Kentucky and Indiana. Its total length is 5 294 feet, consisting of twenty-seven spans, of various lengths from 50 to 250 feet, on the Fink plan, placed below the grade of the road, and 2 channel spans, one 370, the other 400 feet long, placed above the grade of the road. This bridge was commenced in the fall of 1867, and completed in the spring of 1870. The channel spans are of a peculiar design, a modification of the triangular plan of bracing—by introducing auxiliary trusses between the main braces. The feet of the main braces are 56 feet 7¼ inches apart, and by the auxiliary trusses this space is divided into four parts, giving a support to the stringers upon which the track rests every 14 feet 1¾ inches. The height of the truss is 46 feet. Each side of the bridge consists of two separate trusses, which are simply bolted together. The chords are of cast iron, the braces having to resist compression of wrought iron, and the tension members also of wrought iron.

The following is a statement of the quantity of iron in some of the principal spans :

	Cast iron.	Wrought iron.	Total.
400 feet span.	570 585 lbs.	834 880 lbs.	1 405 465 lbs.
370 " "	480 953 "	640 095 "	1 121 048 "
245½ " "	216 119 "	215 803 "	431 922 "
180 " "	123 308 "	91 259 "	214 667 "
150 " "	101 453 "	70 224 "	171 677 "
100 " "	58 725 "	29 183 "	87 908 "
50 " "	7 557 "	15 801 "	23 358 "

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15. *Detail Drawing of the Rock Island Draw-Bridge. Designed and built by* C. Shaler Smith, C. E.

The Rock Island Bridge crosses the Mississippi River, connecting the cities of Davenport, Iowa, and Rock Island, Illinois. It was built for the United States Government in 1871, and accommodates the highway travel on the lower floor, and the railway service on the middle deck. The pivot span is 368 feet in length ; weighs, above the rollers, 1 505 000 pounds, and has two floors, respectively 37 and 23 feet wide. This great wind surface, combined with the weight (the entire rotating mass weighs 1 564 000 pounds), and the fact that one end of the span is under the lee of the United States Depot Arsenal, and that the bridge is exposed to heavy wind storms, which, when blowing from the North-east, East or South-east, act on only one end of the span, made the designing of a suitable turn-table a matter of the utmost importance. The plan decided upon was that shown in the drawing here described. A cast-iron circular girder, 30 feet in diameter, 5 feet in depth, web 2 inches thick, and flanges 15 inches wide, rests upon a live ring composed of 34 wheels, each 30 inches in diameter and 14 inches face. The traveling weight borne by each of these wheels is 44 250 pounds. To secure perfection of action, a revolving frame, the full size of the circular girder, was first constructed at the machine shop where the turn-table was built, and on this the girder and wheel track were planed to an exact level. The wheels were all turned to a gauge, and the entire table fitted together on the revolving frame, so as to test the fitting of every part.

The span is rotated by two hydraulic rams, each of 10 feet stroke and 5 inches diameter of piston. These are placed over the circular girder, one on each side of the span, in a vertical position, and are worked by a double cylinder engine, each cylinder being 6 x 8 inches. The force pumps are four in number, each with 1½ inch piston. The rams are reciprocal, each being the reservoir for the other, and the office of the pump is to transfer the liquid from one ram to the

other. Both rams are thus under the same pressure at all times, and hold the span in equilibrium. except while the pumps are shifting the fluid from right to left, or *vice versa*. Owing to the very low temperature at which the span is often required to be moved, a non-freezing liquid was necessary in order to operate the rams. A mixture of glycerine and water—fifty per cent. of each—was found to be the best for this purpose. The power of the rams is transferred to the pier by means of a wire rope. 1½ inches diameter, arranged as in an Armstrong crane. The frictional resistance to rotation at the centre of the live ring wheels is 7 $\frac{36}{100}$ pounds per 1 000 pounds of superincumbent weight.

The pivot span supported by this turn-table is peculiar in that it is proportioned without dead weight reactions under the end supports, that the top chord is composed entirely of eye-bars, that every panel point in both chords is hinged vertically, and that all lateral connections are hinged horizontally.

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16. *Detail Drawing and Photographs showing method of erection of the Kentucky River Bridge, Cincinnati Southern Railroad. Designed and built by* C. Shaler Smith, C. E. (See Plate XLV.)

This bridge crosses the cañon of the Kentucky river, 112 miles South of Cincinnati, at an elevation of 275 feet above the low water level of the river. The six photographic views show the mode of erection of the structure at its various stages, and the drawings appended portray the typical parts of the truss and piers. The peculiarities of the truss are as follows: The middle portion is a continuous girder 525 feet long, supported by piers placed 375 feet apart, and supporting two discontinuous spans, each 300 feet in length, at the ends of projecting cantilevers extending 75 feet from each pier. The upper and lower chords are riveted throughout, except at the cantilever points where the upper chord is hinged and the lower chord fitted with sliding tenons, so that motion from load or thermal changes may be uninterrupted. All connections of the web members to the chords are hinged. The piers are composed of four legs each, and are given a base sufficient to prevent tension on the leeward legs under any condition of load or violence of wind. For convenience during erection, and to accommodate thermal changes, each pier pedestal is placed on a double set of friction rollers, so as to admit of motion in any horizontal direction. The connection between span and pier consists of a pin 12″ in diameter, thus making a fixed joint and permitting a rocking motion only. The piers were placed 375 feet apart when the thermometer was at 60°, and are perfectly vertical only at this temperature. The additional strains caused by the expansion of the truss and momentum of a train weighing 1 100 tons and supposed to be brought to a rest on the bridge after entering it at 30 miles per hour, have been

computed, and the necessary extra material added to the legs and braces to resist them. At the hinging points both web systems are united in one, in order to avoid any ambiguity of strains ; and to render this more exact, the union is effected by means of a hinged link placed at the angle of the resultant between the tie bars of both systems. The action of spans, piers, and hinges, under loads and during changes of temperature, leaves nothing to be desired, and the novelties in construction and mode of erection proved to be practical successes.

17.—*Drawings and Details of Street Bridge over the Pennsylvania Railroad at Forty-first street, Philadelphia, Penn.* WILSON BROS. & Co., Engineers. (See Plate XLVI.)

The superstructure of this bridge is constructed on a stiffened triangular truss system, entirely of wrought iron. It has two trusses with outside sidewalks, and an ornamental finish at the entrances of cast and galvanized iron fastened to the wrought iron framework. The floor beams are of wrought iron, suspended built beams, placed across from truss to truss at the panel points. Upon these rest longitudinal floor joists of white pine. The roadway and sidewalks are of double thicknesses, the sub-flooring for each being of two-inch white pine, the top flooring for the roadway of three-inch white oak. and that for the sidewalks of one and a half inch yellow pine, tongued and grooved and dressed on the upper surface. The upper chords of the trusses and the vertical posts are formed of rolled plates and angles, and the lower chords and inclined ties of link bars, with pin connections throughout.

The principal dimensions are as follows :

Span, centre to centre of end lower chord pins..........	213 ft.	4	inches.
Height of truss, centre to centre of chord pins..........	21 "	4	"
Number of main panels, ten.			
Number of sub-panels, twenty.			
Distance between trusses, centre to centre..............	40 "	0	"
Distance centre of truss to centre of handrailing........	10 "	0	"
Entire width of bridge, centre to centre of handrailing..	60 "	0	"
Clear span between masonry on the square.............	185 "	$9\frac{7}{32}$	"
Clear span between masonry on the askew..............	209 "	3	"
Angle of askew..................................	62° 35′ 47″		

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18. *Detail Drawing of 520 feet iron truss of Cincinnati Southern Railway Bridge over Ohio River at Cincinnati. Built by Keystone Bridge Co.,* J. H. LINVILLE, C. E., President. (See Plate XLVII.)

The portion of this bridge constructed by the Keystone Bridge Company, under their contract dated February 24th, 1875, embraced the

BRIDGE OVER THE PENNSYLVANIA RAILROAD AT FORTY-FIRST STREET, PHILADELPHIA, PENNA.

JOSEPH M. WILSON, ENGINEER.

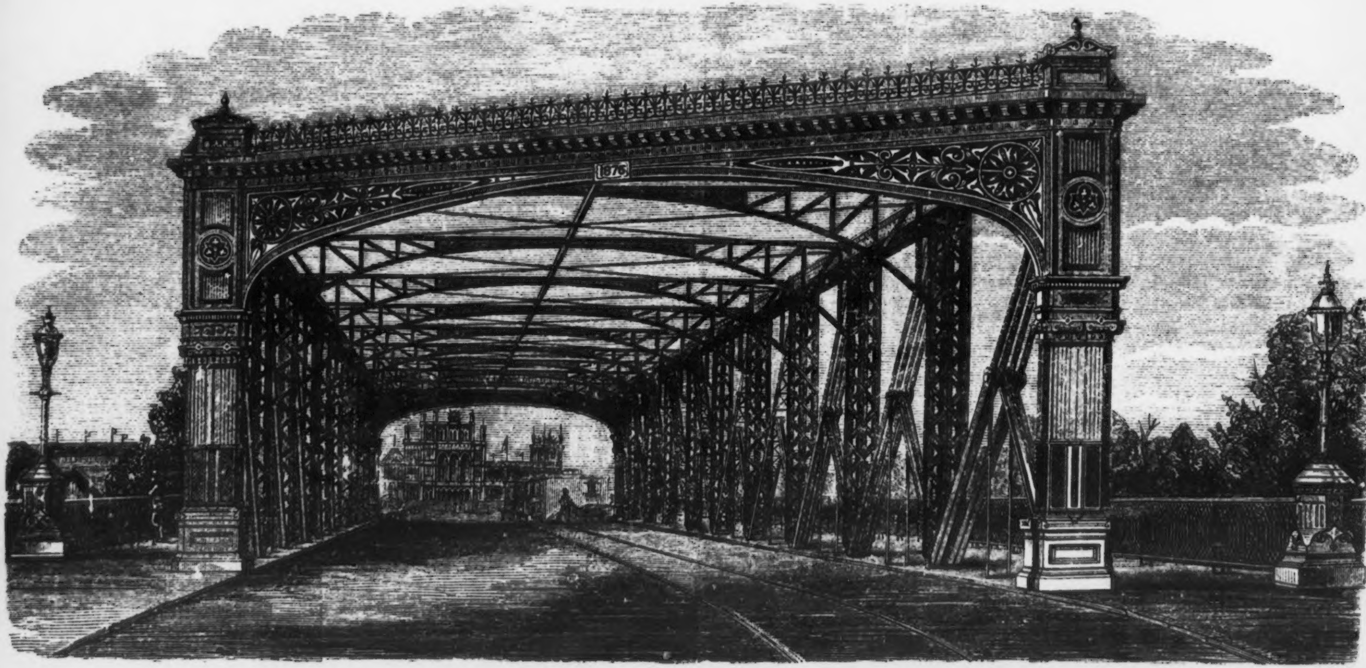
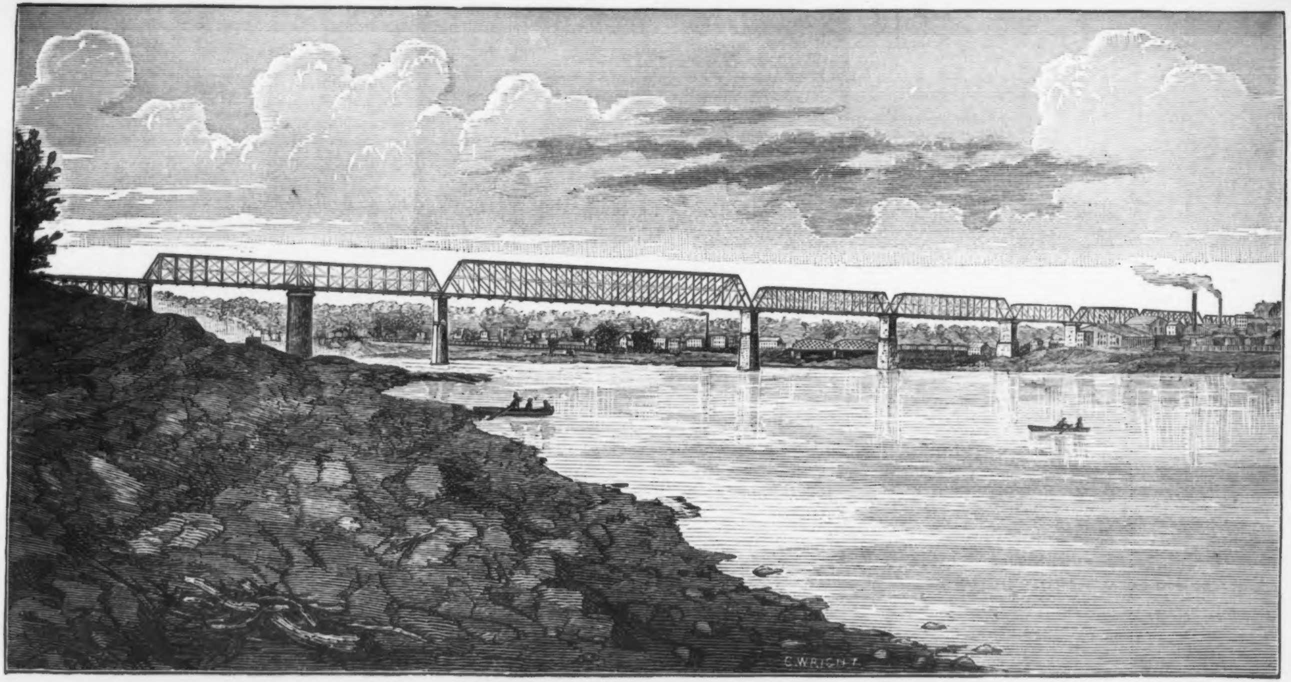


PLATE XLVI.
TRANS. AM. SOC. CIV. ENG'R'S
VOL. VII. Nº CLXXIV.
PARIS COMMITTEE.

Plate XLVII.



southern abutment and piers numbers 1 to 6 inclusive, and the superstructure for the following spans, viz. :

One Deck Span.............................. ..110 feet.
One Pivot Span................................370 "
One Channel Span............ ....519 "
Two through Spans ....300 "

Making a total length of 1 599 feet, measured from centre to centre of piers.

The general data are as follows :

	Span 1.	Span 2.	Span 3.	Span 4.	Span 5.	Total.
Length, centre to centre, piers.........	110′	370′	519′	300′	300′	1 599′
" " " pins.........	108′ 0$\frac{23}{32}$″	365′ 4″	515′	295′ 1″	295′ 4″	
Depth, " " chords......	15′ 6″	36′ 6″	51′ 6″	37′	37′	
Width, " " trusses......	10′ 0″	15′ 6″	20′ 0″	15′ 10″	15′ 10″	
Weight of Iron.............. . lbs.	104 400	826 500	2 634 400	657 400	657 400	

Masonry for Spans 1 to 5 inclusive.......12 621 cubic yds.
Concrete .... 500 " "

The contract price was $663 570.00. with a provision for contingencies, which increased the entire cost to about $700 000.

The designs for the superstructure were submitted by J. H. Linville, C. E., President of the Keystone Bridge Company, and embraced his latest improvements. These plans were slightly modified by the engineer of the railway company, the work being constructed under his supervision, and subject to his approval.

The lower chords are placed at an elevation of 43.25 feet above high water and 105.65 above low water.

The trusses of the channel span are trapezoidal, consisting of 20 equal subdivisions or panels, with vertical intermediate posts, and inclined end posts, the tension diagonals reaching two panels, and being inclined at an angle of 45 degrees.

The lower chords have rectangular ends, and are packed closely together, forming a flat bearing on their upper surface for the bases of the posts, and a recessed bearing on under side to receive the suspended floor girders and resist the action of the lower lateral ties.

To give greater width of truss, twin rectangular posts were used, stiffened at the middle of the height by longitudinal struts extending, between posts, from end to end of the trusses. At the intersection of these struts with the posts transverse struts and diagonal ties were introduced to serve as wind bracing, and maintain the lateral stability of the trusses.

Floor girders are 4 lines of stringers, of wrought iron built beams, which support the long wooden ties and guards.

The bridge is designed to sustain, in addition to its dead weight, the following rolling load, at a speed of 30 miles per hour, viz., two locomotives coupled, each weighing 36 tons, on drivers in space of 12 feet, total weight of engine and tender loaded 66 tons, in space of 50 feet, and followed by loaded cars, weighing 20 tons, in 22 feet. An addition of 10 to 30 per cent. is added to the strains produced by the rolling load (considered as static) in the calculation of floor beams, stringers, suspension links, counter rods, and all other parts of the bridge liable to be strained suddenly by the passage of a rapidly moving load.

Wind pressure of 50 pounds per square foot is provided for.

Tensile strains were limited to 10 000 pounds per square inch on best double refined iron. Strain of compression in large rectangular chords to 8 000 pounds per square inch. And on posts the strains were limited to 6 000 pounds per square inch,

The bridge was constructed at the shops of the Keystone Bridge Company, Pittsburgh, and erected on trestling consisting of three tiers of lower scaffolding and two tiers of upper falseworks. It required the labor of 60 men 24½ days to raise the iron work and put it in place preparatory to swinging the trusses clear of the scaffolding.

All the iron used in the structure was tested by specimens. Special forms of joints were tested to breaking to determine their proportions, and all lower chords and suspension bars were tested to 20 000 pounds per square inch.

The channel span was subjected to a test load of seven locomotives coupled and four flat cars—weight, 966 000 pounds. The maximum deflection was $2\frac{3}{32}$ inches.

Model of Point Bridge across the Monongahela River at Pittsburg, Pa. Loaned to the Society by the American Bridge Company.

Point Bridge was designed by Edward Hemberle, Engineer of the American Bridge Company. It consists of tower and chains, with platform suspended therefrom in the same manner as in a regular chain suspension bridge. To this is added a stiffening system above the chains, and rigid posts arranged between chains and platform so as to prevent the roadway from undulating or oscillating independently of the structure above. The stiffening appliances above the chains consist of rigid chords running in straight lines from the top of the tower toward the center of the chain, and connecting thereto by a hinged joint at each end. Between these chords and the chains there is a system of bracing, composed of posts and diagonal tie-rods, all connections being pin-jointed. The chain, being a catenary, or curve of equilibrium, bears all the permanent load of the structure without straining the stiffening trusses. This object was accomplished by erecting the bridge completely

before connecting the ends of the straight top chords to the centre joint. The rods are provided with turn-buckles, and are so adjusted as to be strained under moving loads only.

The total length of the bridge is 1 245 feet from back to back of anchorages, with one middle span of 800 feet between centres of piers, and one independent trussed side span of 145 feet in length at each shore. The roadway rises from both shores toward the centre of the channel, with grades not exceeding 3½ feet in 100—the highest point of the roadway being 83 feet above low water. The saddles upon which the chains rest on top of the towers are 180 feet above low water. The deflection of the chain is 88 feet, which is considerably more than is usual for supension bridges, but the stiffening allows of increasing the deflection and thereby reducing the strains in the chains as well as their weight. The bridge is 34 feet wide from centre to centre of outside railings, and this space is divided into a roadway 21 feet wide and two sidewalks of 6½ feet each.

Photograph showing iron derricks used by the Passaic Rolling Mill Company, of Paterson, New Jersey, in the erection of the New York Elevated Railroad.

These derricks were designed by Mr. Watts Cook, President of the company. The smaller one consists of two trucks, one carrying an iron hoisting frame and the second a hoisting engine; the two trucks are coupled together, and in use their wheels rest on the girders already placed in position; the forward arm of the hoisting frame reaches to the centre of the span to be erected while the rear arm is anchored down; with this derrick a gang of twelve men have erected 210 tons of iron in ten hours. The larger derrick has but one truck, which runs on rollers instead of wheels, the power being placed at the centre of the frame, which is 108 feet long and has a reach of 50 feet.

Large crayon perspective drawing of the East River Suspension Bridge connecting the Cities of New York and Brooklyn. Loaned to the Society by MR. WILLIAM HILDERBRAND.

Three sections of wire suspension bridge cables, being full-sized models of the cables of the East River, Cincinnati and Niagara Suspension Bridges. Loaned to the Society by JOHN A. ROEBLING'S SONS.

Album of photographs and portfolio of drawings of bridges built and designed by CLARKE, REEVES & CO., PHŒNIXVILLE BRIDGE WORKS.

Album of photographs of bridges built by KEYSTONE BRIDGE COMPANY.

Portfolio of photographs, etc., of bridges designed by WILSON BROTHERS & CO., of PHILADELPHIA.

HYDRAULICS.

WATER AS APPLIED TO COMMERCIAL INDUSTRIES AND DOMESTIC PURPOSES WITHIN THE UNITED STATES.

Among the earlier immigrants to this country there were many mechanics and artisans, and the small streams in the neighborhood of settlements were soon utilized for the purposes of grist and saw mills, to which later were added tanneries, card and fulling mills. With the organization of the States under one general government, the necessities of means of communication and of exchange of commodities, called attention to the improvements in inland navigation adopted in other countries, and rivers began to be improved by the construction of dams, with supplementary canals around dangerous falls, as early as 1792. From these small beginnings, other canals were projected and carried out through the Northern and Middle States, so that at the inception of railroads, say in 1835, there were in the United States over 3 500 miles of navigable canals, and many miles of slack water navigation. With the introduction and spread of railways, the construction of canals almost entirely ceased, and many already in operation were discontinued, but many of the important ones have been improved, and their carrying facilities increased, and at this time the tonnage of the canals, consisting mostly of grain, coal, lumber, and heavy materials, is an important factor in our internal commerce. The Erie Canal, built by the State of New York, to connect the waters of Lake Erie with those of the Hudson River, com-

pleted in 1825, did much to develop the resources of the State, and to establish the City of New York as the largest port of the United States. Its enlargement was commenced about 1840, and completed in 1862. Its present depth of water is 7 feet, and maximum capacity of boats 240 tons. Its cost to 1876 was $49 000 000, and the tonnage for the year 1877 was 857 305 563 tons, carried one mile, whilst that of the New York Central Railroad, during same year, was 1 619 948 685 tons one mile. The length of the main Erie Canal is 352 miles, and with connections and feeders, 907 miles; movement on all those canals, about 5 000 000 tons. In Pennsylvania, the canals are used largely for the transport, of coal. The Lehigh Coal and Navigation Company transported by their canals, in 1876, about 1 000 000 tons; the Delaware and Hudson Canal, 1 300 000 tons; the Schuylkill and Susquehanna about the same, and the Pennsylvania Canals about 900 000 tons. The Chesapeake and Ohio canal carries on a large coal trade between the Cumberland coal region and Washington and Alexandria.

The Morris Canal, in New Jersey, connecting the Delaware River with New York Harbor, with feeders extending into the coal region, still continues to do a considerable coal trade. On this canal the experiment of inclined planes was first tried and they are still in successful use. Along the Eastern coast, by the connection of the sloop canal of Albemarle Sound with Chesapeake Bay, Chesapeake Bay with Delaware Bay, and Delaware Bay with the Raritan River, there is inland navigation from Albemarle Sound to New York City.

In Illinois, the Illinois and Michigan Canal, from Chicago to La Salle, opens the navigation between the Great Lakes and the Mississippi River, and carried in 1873, eight million bushels of grain, and 50 million feet of lumber, besides large freights in shingles and laths. There is a short canal at Sault St. Mary's, connecting the navigation of Lake Superior with that of the other Great Lakes.

As said above, at a very early date, the small streams in the neighborhood of settlements, were utilized for saw and grist mills and the like, but it was not till the war of 1812–15, when an embargo was laid upon our commerce, that capital began to be used largely in industrial works, first by individuals or small firms, developing the old water powers, for the driving of cotton and woollen mills; thence still further utilizing the smaller streams, like the Charles, the Blackstone and the Passaic. But with the increase in demand for goods, and profit in their manufacture,

the necessity for large mills was recognized, and as large capital was not in single hands, corporations of combined capital were organized to develop large water powers for more extensive industries. It was found in 1821, that the old canal of the Locks and Canals on the Merrimack could be made readily available, and the whole water of the Merrimack, with a fall of 30 feet, could be made use of, and this power, it was supposed, would supply an almost indefinite demand. The Locks and Canal Company became the owners of nearly all the land in the neighborhood of the canal within the limits of the present City of Lowell, and sold land with mill powers, a mill power being equivalent to 25 cubic feet per second on a 30 foot fall. At the present time they are running up to about 200 mill powers. With the success of Lowell, water companies on the same basis were organized throughout the different States, water power and land belonging to these corporations and the mills to others. Manchester and Lawrence were built on the Merrimack; Lewiston on the Androscoggin; Biddeford on the Saco; Bellows Falls, Turners Falls, Holyoke and Windsor Locks on the Connecticut; Ansonia on the Naugatuck; Derby on the Housatonic; Cohoes on the Mohawk; Rochester on the Genessee; Paterson and Dundee on the Passaic; Trenton on the Delaware; Manayunk on the Schuylkill, and many others.

At the first the science of hydraulics was but little understood and capital not abundant; the dams were mostly of timber, and the canals of but little capacity. Now most of the dams are substantial structures, and canals of such section that the velocity of the flow is often less than 2 feet per second.

The earlier water wheels were almost invariably over-shot, pitch-back, or breast wheels. Many were of large dimensions, and well constructed, with cast iron shafts. The percentage of useful effect was sometimes as high as 80 per cent., but the average was considerably below 70 per cent.

But with the introduction of the Fourneyron wheel in France, the attention of engineers here was called to it, and Mr. Edward Morris constructed and put into operation one near Philadelphia, which indicated 75 per cent. of useful effect. In 1844 Mr. U. A. Boyden constructed one for the Appleton Company at Lowell which gave 78 per cent., and in 1846 two for the same company which gave 88 per cent., and many other wheels with equally good results.

The quantity of water was invariably determined by the flow over a wier, and the mechanical effect by a Prony dynamometer, and as

the compensation of Mr. Boyden was dependent on the percentage of useful effect obtained, it became very important that the formula for the flow over wiers should be rigorously determined. And as the formula thus far was derived from discharges of water and breadth of weir much less than were necessary for comparison with the discharge of large turbines, Mr. James B. Francis, at the expense of the Locks and Canals Company of Lowell, undertook a long course of trials, which have been published under the title of "Lowell Hydraulic Experiments," and as the most satisfactory form of formula Mr. Francis adopted that recommended by Mr. Boyden, in which the correction of length of wier for end contractions is a factor of the depth on the wier, and in taking the heights of water above the wier he adopted Mr. Boyden's hook gauge as the most accurate. The formulæ obtained by Mr. Francis are now the standard throughout this country, and are adopted wherever a wheel is to be tested.

The success of Mr. Boyden's wheels were due to their design and to the accuracy of their mechanical details and finish, the later wheels having bronze buckets to the wheels and guides. They were as expensive as steam engines of the same power, but they still endure after years of work.

Wheels of this form were more adapted to mills than the old breast or over-shot wheels, occupying a great deal less space, running at a more suitable speed, and more easily regulated, and when it was demonstrated that the percentage of effect was greater, the manufacture of reacting wheels spread throughout the country. Jonval wheels were built at Philadelphia, Patterson, Cohoes, and various forms were experimented on elsewhere to secure high percentage of useful effect, with cheapness of construction. At the first it was not possible to exceed that already obtained by Mr. Boyden, but it was thought possible that wheels of cheap construction and with a very fair percentage of effect could be made. This has been done; the forms now most generally adopted are wheels with a central and downward discharge; and makers, before issuing circulars to the public, either test their wheels at their works or have them tested by weir discharge and Prony dynamometer, and their guarantee of power is based generally on a standard of 80 per cent. of useful effect.

Water for manufacturing purposes is estimated by cubic feet of discharge multiplied by feet of fall. In California, where the water is used

for washing earths and ores, water is sold by the inch, that being usually the quantity which escapes through an orifice one inch square with the water six inches deep above the top of the orifice ; as measured an inch of water is considered equal to $2\frac{1}{2}$ cubic feet per minute. The mining ditches of the State (1871) carry at least 100 000 inches, or about 2 500 000 000 gallons in 24 hours. This water is carried in open canals, in wooden frames and iron pipes. The latter are used now invariably in crossing deep ravines, and the necessities of the positions have led to the adoption of heroic engineering precedents in regard to the thickness of metal, coupled with diameter of pipe. Thus the Swartsville pipe, 16 inches diameter, under 180 feet pressure, of No. 18 sheet iron, was laid in 1861, not painted inside but painted on the out. San Juan, 30 inches diameter. Nos. 12 and 14 iron, 55 feet head, coated inside and out, laid in 1861. Chinese camp, Nos. 12, 14, 16 and 18 iron, maximum head 800 feet, was laid in 1868. The pipes are double riveted on the longitudinal seams, put together like stove pipes and riveted, and coated with coal tar.

Most of the water thus distributed is used, as is said, "to hydraulic," that is, to wash banks of auriferous earth by throwing a stream of water upon them through a hose and pipe. Hydraulic claims are usually in hills. The water is brought to the bottom of the hill by an iron pipe or by a hose. The hose is of heavy duck, and from 4 to 10 inches diameter, sometimes surrounded by iron rings 2 inches wide and 3 inches apart, connected by 4 ropes. It is important to preserve as great a head as possible, with flexibility of hose. The nozzles are like those of fire engine hose, sometimes as large as 8 inches diameter, with a discharge of 300 to 800 inches of water. The miners usually turn the stream upon the banks near the bottom until a large mass of earth tumbles down. They then wash all this away into the sluice, and then cut the bank again at the bottom. The water usually costs 10 cents per inch per day, and dirt in this way has been in some places excavated at a profit when it contained one cent's worth of gold in a cubic foot. The same hydraulic process has been used for excavation merely.

Besides water for washing earths, canals are used in California for irrigation, and in 1876 there were 915 irrigating ditches supplying water to 90 344 acres.

City Supply.

Few of even the medium sized cities of the United States are without some system of water supply and distribution. Philadelphia was first in

the inception of such works, which was effected by the construction of a dam across the Schuylkill, with breast wheels and pumps raising water into a reservoir and then distributing it through the city. The breast wheels have given way to more efficient reactors, and the supply has been supplemented by steam pumping engines, both on the Schuylkill and on the Delaware.

New York is supplied by gravitation, bringing the water from the Croton through some 38 miles of brick aqueduct and some iron conduit. The iron conduit or pipe lines across Harlem and Manhattan Valley have been increased in capacity. A large receiving reservoir of 1 000 000 000 gallons capacity, and two large catch basins on the Croton river have been constructed since the completion of the works ; together with two pumping engines, of 10 000 000 gallons per 24 hours' capacity, for the supply of the highest parts of the city. The daily supply is now about 90 000 000 gallons.

Boston has also a gravitation supply from Lake Cochituate, but has lately constructed an entirely new aqueduct, taking all the upper waters of the Sudbury river. By the annexation of Charlestown, the pumping works of Mystic pond have been added. The total daily supply is now about 30 000 000 gallons.

The supply of Washington is also by gravitation from the Potomac, and is the largest in quantity in proportion to the number of its inhabitants.

But, in general, most of the cities are supplied by steam pumping engines, of which the exhibit of St. Louis is a very fine type, and, together with those of Messrs. Leavitt and Worthington, represent our best practice.

Usually with all city water works there are reservoirs. In some cases the pumping is directly into the main, without reservoirs. In Sandusky the engineer, Mr. J. D. Cooke, has introduced, as an economical construction, under the conditions of position, a very large stand pipe, serving, in a measure, as a reservoir, with a small central pipe which will be useful in putting an extra head on the mains in case of fires. The large pipe, 25 feet inner diameter, 180 feet high ; the central pipe 8 feet diameter, 230 feet high. The large pipe is of steel plate, having a reliable tensile strength of 70 000 lbs. The plates build 4 feet per course, each course being composed of 6 plates, 1st and 2d course $\frac{7}{8}''$ thick, 3 rows of $1\frac{1}{8}''$ steel rivets, then reducing by each two courses the thickness of the

plates by $\frac{1}{32}''$; the 43d and 45th course, inclusive, is $\frac{3}{16}''$ plates, $\frac{1}{2}''$ rivets, double. The rivets were changed from triple to double rows at 24th course. The top is finished with galvanized iron cornice ; the whole thoroughly painted, inside and out. Influent and effluent pipes pass into and through the shell of large pipe near the bottom. Either pipe can be used independently of the other ; valves so arranged that the engineer can change to either pipe without leaving the engine house.

The types of pumping engines used at the different works are extremely varied. The drawings sent to the exposition are very favorable specimens of American practice. The pumping engines of Mr. Leavitt are compound engines, with the steam cylinders inclined to each other, and at their bases are close to each other as possible. The connections are with opposite ends of the beam, and the channels between the cylinders are short as possible. The fly-wheel connection is with one end of the beam and the pump connection with the other. This type of engine, of which there are three in operation—one at Lynn and two at Lawrence—both in their tests by experts and every day running, have given the best percentage of effect of any in the country.

The Worthington engine is the legitimate growth from the donkey engine which was first introduced for the feed of boilers by Messrs Worthington & Baker. In its present form, as a pumping engine for water supply to towns, it is a compound horizontal engine, with two sets of high and low pressure cylinders, and its distinctive character is, that the steam valves of one set of cylinders are moved by the piston rods of the other. There are, probably, more of these engines than of any other one type ; they are well adapted to a very fair percentage of duty, and they are economical, in first cost including foundations, and repair in working. They are of medium size, the largest in operation having a capacity of 8 000 000 gallons per 24 hours.

The St. Louis engines are of the largest capacity of any in this country. Engines Nos. 1 and 2, high service, are simple beam engines, with the pumps beneath the steam cylinders and directly connected ; the crank connection is with the opposite extremity of the beam. The pump is of a type first introduced by Mr. Wm. Wright at the Brooklyn Water Works. The pump cylinder being enclosed in an annular cylinder, acting as a supplementary pipe to the pump, and affording more ample passage for the water than could be secured through the pump bucket alone. Engine No. 3, High Service, is a coupled compound beam engine, with

the two steam cylinders set close to each other and attached to the same side of the beam. The pump and crank connections are with the opposite ends of the beams. At the low service the water is pumped from the river into subsiding basins, and thence, by the high service, into the mains and reservoir. Engines Nos. 1 and 2, low service, are Bull engines, that can be run coupled. No. 3 is a beam engine, with two plunger pumps, one beneath the steam cylinder and directly connected therewith. On the piston-rod there is a connection with the extremity of a beam, at whose other extremity there is another pump and a flywheel connection. This pumping engine has two distinct condensers, the first in connection with a regular air pump on the main piston-rod, which is supplied by injection from the clear water main of the city, and the condensed water is used entirely for the supply of the boilers, at from 140° to 150°. The other is a syphon condenser supplied from the pump chamber with river water and the condensation is effected by means of a sprinkler. All this condensed water is returned to the river.

Of late, all the pumping engines of a capacity of 5 000 000 gallons per 24 hours, and above, have been fitted with compound engines. The St. Louis engine, No. 3, may represent the type of Milwaukee, Chicago and Lowell. In the Yonkers engine Mr. Wright has placed the cylinders vertically and at opposite ends of the beam. There are a great many Bull and Cornish engines used for the supply of towns and drainage of mines, and the English pump of Drury has been introduced into California. The pumps of the Holly system are inclined cylinders, with directly connected pumps beneath and a connection above with a crank on a fly-wheel shaft, usually with four cylinders, two at each end of the shaft, and arrangements to work either simply or compound.

The forms of boilers are, perhaps, more varied than that of the engines. The most usual types are the *horizontal tubular*, fired underneath and returning through the tubes; the *drop flue*, horizontal with large flues to a back connection, then returning through smaller flues or tubes to a front connection, thence out at the bottom and back to the chimney; and the *Cornish*.

SUBJECTS EXHIBITED.

19. *Photographs of Pumping Engine at Lawrence, with Indicator Cards, &c. Designed by* E. D. Leavitt, Jr., C. E. (See Plates XLVIII, XLIX.)

The engines are two, with a single fly-wheel between them. The two steam cylinders, both steam jacketed, are placed beneath the main centre of a working beam, and inclined outwardly at the top to connect with opposite ends of the beam, reducing thereby the length of the steam passage between the cylinders, equalizing the stroke, and economizing space, with a strong and compact frame.

The cylinder valves are all gridiron valves, with large area of opening and small movement. The steam valves to the high-pressure cylinders are operated by cams controlled by governors, one to each engine. When running coupled, the cam of one engine is set and the other controlled by its governor.

Air-pump double-acting; feed-pump connected with air-pump rod. The pumps are of the Thames Ditton variety, bucket and plunger, but with a supplementary delivery pipe. There are seven double-beat valves for suction, and four in the supplementary pipe, and the bucket valve for the delivery. Attached to the lower valve chamber there is a small spherical chamber with an air-cock at the top, by which air may be introduced into the pump, which is found, at particular stages of water in the well, to contribute to ease in the working of the pump.

TABLE OF DIMENSIONS.

Diameter of high-pressure cylinders	18	inches.
" low " "	38	"
" high " " rods	3½	"
" low " " "	4	"
" air-pumps	15	"
" pump-barrel	26⅛	"
" " plunger	18½	"
" " " rod	4½	"
" bottom and supplementary valves outside lower seat	15¾	"
" " " " " inside upper "	12½	"
" bucket-valves outside lower seat	22	"
" " inside " "	15	"
" air-chamber	54	"
" fly-wheel	30	feet.
Length of stroke of steam and water pistons	8	"
" " air-pump	28	inches.
Distances between End Centres of Beam	16½	feet.
Lead on steam-valves	0	

Lead on high-pressure exhaust valves	$\frac{1}{16}$	inch.
" low " inlet	$\frac{1}{16}$	"
" " " exhaust bottom	$3\frac{5}{16}$	"
" " " " top	$4\frac{9}{16}$	"

All measured on stroke of pistons.

Cushion on high-pressure top exhaust	$14\frac{1}{4}$	"
" " bottom "	$14\frac{3}{4}$	"
" low-pressure top "	$4\frac{1}{2}$	"
" " bottom "	$8\frac{1}{4}$	"

VOLUME OF CLEARANCE AND PORT SPACE:

High-pressure top	.0256	of cylinder capacity.
" " bottom	.0231	" "
Low " top	.0154	" "
" " bottom	.0182	" "
Connecting pipe between cylinders	.0992 H. P.	" "

Weight of fly-wheel	35 900 lbs.
" walking-beam, including pins and counter-balance	25 700 "
" high pressure piston and connections	2 575 "
" low " " " "	4 175 "
" air-pump " " "	1 800 "
" pump, plunger bucket	7 200 "
" main connections, beam to crank	3 800 "

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20. *Photographs of Pumping Engines of St. Louis Water Works.*

The photographs exhibited of the engines of the St. Louis Water Works are three in number, representing three of the four types of pumping engines employed at these works. The fourth type is not represented.

The first type is No. 1, low service engine. There are two engines precisely of this type. They are Cornish engines, of the kind introduced by Capt. Bull. The principal dimensions are as follows: Diameter of steam cylinder 56", stroke 144", speed $8\frac{1}{2}$ to 9 strokes per minute, air-pump 28" diameter, stroke 72". Main pump 56" × 144", being the same as the steam cylinder. The pump is a plunger pump. The lift of water is from 15 to 50 feet, according to the stage of water in the Mississippi river, from which the supply is taken.

The capacity of each pump is 17 000 000 United States gallons in 24 hours. These engines were built by the Knapp Fort Pitt Foundry Co. of Pittsburgh, Pennsylvania, in 1870. The pump valves and seats are of composition, "Government standard," viz.: copper, 85 per cent., tin, 10 per cent., spelter, 5 per cent. The valves are "Cornish Equilibrium," arranged in two tiers of twelve valves each. Diameter of lower valve seat 17", of upper valve seat 15", lift of valve $1\frac{1}{4}$". These two engines were erected by the parties above mentioned, in accordance with a proposal made by them on February 15, 1868, to construct the two

engines for $89 800. Steam for these engines is supplied by two internally fired fixed boilers, two for each engine. They have each 650 square feet heating surface, and 27½ square feet of grate surface. The boilers are 7 feet diameter and 30 feet long, the flues 30″ diameter, the full length.

The second type of engine is Engine No. 3, low service, a crank and fly wheel engine with Wright's valve gear, built by Gerard B. Allen & Co. of St. Louis, 1874. The contract was awarded in accordance with a proposal made on November 11, 1872, to construct the engine for $118,500. The principal dimensions of the engine are as follows: Steam cylinder 60″×84″ without steam-jacket, air pump (single acting) 26″×84″. Two main pumps 50″×84″ each. The pump valves are of leather and hinged, placed in the central chamber in two tiers. The capacity was intended to be 1 000 000 United States gallons per hour. The action of the valve gear is excellent. The lift of water is that already stated for Nos. 1 and 2 engine, viz.: from 15 to 50 feet.

The third type of engine is Nos. 1 and 2, high service engines, which are alike. No photograph of this type is exhibited. The engines are very similar to No. 3 Ridgewood engine at the Brooklyn Water Works, described in Mr. Kirkwood's book, "The Brooklyn Water Works." The engine is a crank and fly wheel engine with a beam. The principal dimensions are, steam cylinder 85″×120″ (jacketed). Air pump 36″×60″, double acting. The main pump is directly under the steam cylinder, and worked by an extension of the piston rod. The pump is a bucket and plunger pump of the kind known as "Thames Ditton." Diameter of plunger 36½″, of bucket 51½″, stroke 120″. The pumps receive water through a 50″ pipe, and discharge through a 36″ main. Air chambers of ample capacity are located near the pumps. The pump valves are "Cornish Equilibrium." There are 11 suction and 10 discharge valves. Diameter of lower seats 16″, of upper 13¾″, lift of valves 1¼″. There is also a large bucket valve of the same kind. The lower seat is 40½″, the upper 34½″ diameter, the lift 4″. The steam valve gear is of the kind known as "Sickel's," and the cut-off is worked from the parallel motion. Diameter of fly-wheel 26 feet, weight 30 tons. The head against which these pumps work is about is about 200′, and the capacity 17 000 000 United States gallons in 24 hours. These engines were contracted for at $188 800, in accordance with proposal made February 15, 1868, by the Knapp Fort Pitt Foundry Co. of Pittsburgh, Pennsylvania, and were finished in 1870. They have been very satisfactory. The consumption of steam is 25 pounds per indicated horse power per hour, the rate of expansion from 3 to 4, the number of revolutions per minute 11½, though they have been run on a trial at 14½. Steam is usually furnished to each engine by six boilers, each with internal fire place and return flues. The grate surface is 25 square feet, the heating surface 500 square feet to each boiler. The steam pressure is 40 pounds per square inch.

The fourth type of engine is No. 3, high service engine, of which a photograph is exhibited. This engine works against the same head as the other high service engines, but has a capacity of 1 000 000 gallons per hour. The engine is a double beam compound engine. There are two high pressure steam cylinders unjacketted 50″×87″. The low pressure cylinders 80″×138¼″, the cranks are set at right angles on a shaft which carries a fly-wheel 32′ diameter, weight 35 tons. The air-pumps are double acting, each 23″×54″. The main pumps are each of the "Thames Ditton" kind, plungers 32″, buckets 45¼″ diameter, and 100″ stroke. The pump valves are "Cornish Equilibrium," and the steam valves are driven by spur gearing on the shaft. The action of the pumps is exceedingly smooth. The contract for these engines was awarded to the Hartford Foundry & Machine Co., on March 19, 1873, for $280 000, and was finished in 1874.

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21. *Photograph of Stand Pipe of Sandusky Water Works. Designed by* J. D. Cooke, M. E.

This stand pipe is described in the general article.

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22. *Photographs of Worthington's Duplex Pumping Engines. Designed by* Henry R. Worthington, M. E. (See Plate L.)

The pumps are in pairs, horizontal and double-acting, arranged side by side on the same frame, each operated directly by a compound engine with steam jacketed cylinders. The smaller steam cylinder is attached to the front head of the larger, and has a central piston rod connecting with pump rod through a cross-head, and two piston rods from the larger cylinder pass outside the smaller and connect with the cross-head. There are two single-acting air pumps, which are operated from the ends of a horizontal beam, with vertical lever attached, receiving motion from one main cross-head. The main valves are plain slides operating over double cylinder ports.

The valves for both cylinders of each engine are arranged on the same stem by raising the chest of the smaller, and each valve is provided with a balancing piston. The valves of one engine are operated by bell cranks directly from the reciprocating parts of the other, and no rotative movements, with accompanying details, are required. Double cylinder ports are provided—the outer ones receive steam past the ends of the valves, and admit same to the cylinder in the usual way; the inner ones communicate with the exhaust cavity of the valve only, and enter the cylinder at such distances from the ends that when steam is exhausting through one of the ports the main piston will run over and close it, and cushion upon the vapor thereby inclosed, the outer port being at the time shut off by the main valve. Valves are provided to put the two cylinder

ports at each end in communication to regulate the extent of cushioning. The pump valves consist of rubber disks arranged in chambers above and below the plungers. . Each plunger runs, without packing, in a long grooved ring in a central diaphragm. In operation, one engine, while in full action, moves the valves of the other, when the pistons of the latter gradually begin to move, and finally attain full velocity, as those of the first are checked by the steam cushions and gradually come to rest, the pump valves meantime seating quietly.

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23. *Photographs of Holyoke Dam and Canal.*

The dam across the Connecticut, at South Hadley Falls, was constructed for the supply of water-power to the proposed town of Holyoke, which, since its construction, has developed into a large manufacturing city. The dam, as originally constructed, was 1017 feet between abutments, with an average height of 30 feet, with a base of 80 feet. It was constructed of timber crib-work, loaded with stone for about one-third of its height. The foot of each rafter is bolted to the ledge underlying the whole dam, and all timbers at their intersections are tree-nailed together with 2-inch white oak treenails. The inclined plank face is loaded with gravel, and the joint at the ledge secured with concrete, The base tiers of ranging timber were 15x15 inches, other timbers were 12x12 inches. The rafters are placed vertically over each other in bents, 6 feet between centres. The planking was of hemlock, 6 inches thick, with oak cross-planking at crest, of 4 inches thick at bottom and 8 inches at top. The crest was plated with ½-inch iron, 5 feet wide. During the construction, the dam was first planked about 30 feet on the incline. A space was then left about 16 feet deep on line of incline, and of length sufficient to vent the flow of the stream. This aperture was closed by a plank flap, as soon as the dam was ready for the filling of the reservoir. The highest freshet has given over 12 feet depth over the crest. By the action of the water, flowing over the crest, the ledge beneath, after a few years, began to be worn and cut out, to the manifest insecurity of the work; there was, therefore, a roll made of similar construction, to that of the main dam, that is loaded crib work and plank face, which gives a discharge at a distance from the structure, and secured its stability. The water power supplied by this dam is perhaps the largest in the United States, utilizing the whole water power of the Connecticut River, with a fall of about 60 feet.

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24. *Photograph and Drawing of Dam across the Mohawk at Cohoes. Designed by* W. E. Worthen, C. E.

The Cohoes dam across the Mohawk is a stone roll to an old crib dam, which had become very leaky and worn, and which, by its over-

fall, had worn deeply into the ledge of slate stone on which it was constructed. The old dam was left as a sort of coffer-dam for the construction of the new dam, and for a protection to it from the shocks of ice. The exterior of the dam was rock faced ashlar, below, and the cap stones were in single lengths of 10 feet, and not less than 2 feet wide by 15 inches thick. They were dowelled together by 2 galvanized wrought iron dowells. The hearting of the work was of small stone, such as could be readily laid by one man; the whole work was laid very carefully and full in cement mortar. The cap stones were bedded in cement, and joints filled to within 6 inches of top, which was then run full of sulphur. The length of the dam is 1,380 feet, with an average depth of 12 feet below crest of dam. In the construction of the dam the leak of the old dam was stopped as far as possible, by a sheet piling attached to the face of the old dam, and another sheet piling parallel with it, and 18 to 20 inches distant, the joints of this last with the ledge were made tight by sausages, or long bags, about 6 inches diameter, filled with dry sand and cement, forced down along the line of ledge and the spaces between the pilings were divided from time to time by cross-pilings, which made a series of boxes of such sizes as could be readily filled at once by batches of concrete. After the setting of the concrete, all pilings except on face of old dam, were removed, and the spaces filled in with grout, and the concrete became a part of the dam, The work was begun July 14th, 1865, and on October 20th of the same year, it was complete, with the exception of 20 feet of coping. The dam at Cohoes, though of insignificant height, utilizes a fall of about 130 feet, and a minimum flow of about 1 000 cubic feet per second.

INTERNAL NAVIGATION.

The United States, early in its history, was noted for its clipper ships, which successfully competed for an important share of the commerce of the world, and as the population rapidly increased advantage was taken of the numerous great bays, rivers and lakes to extend internal navigation in all directions. In due time important lakes and streams were connected by canals, several of considerable magnitude, though small in comparison with the natural water courses thereby united. The demands incident to the rapid development of the country and the individual freedom of thought and action stimulated enterprise and invention, and the means available were quickly utilized to overcome difficulties and accomplish the ends desired.

Under such circumstances steam navigation was developed. Fitch in 1786 showed it to be practicable; Fulton in 1806 put it in such shape that its great value was demonstrated and success assured. The ocean was crossed by steam for the first time by the American steamer *Savannah,* in the year 1819, and the Collins steamers, brought out about the year 1850, were the first in which the heavy head gear used on sailing vessels was dispensed with, reducing the pitching moments, and indicating the general characteristics of modern ocean steamers.

The steamers used in the internal navigation of different parts of the United States are very different in construction and appearance, being specially adapted for the several locations and the duties to be per-

formed. In the sheltered bays and connecting rivers on the coast, side-wheel steamers are generally employed with large, sharp hulls of light draft and little freeboard. The freight is in general stored on the main deck, and passengers are accommodated in cabins and state-rooms above. The main deck is made much wider than the hull, extending to the outside of the paddle wheels, the overhanging portions being called the guards. The cabins are sometimes extended several stories in height and furnished and fitted with all the comforts and luxuries of hotels and dwellings. The hulls are stiffened longitudinally at each side by an arched truss (hog frame), or centrally by a series of king-posts and diagonals, extending from stem to stern. Each boat is in general propelled by the typical American beam engine with skeleton trussed beam supported by a wooden gallows frame. This form gives ample length of connections, and the necessary flexibility and distribution of strain and weight to permit maximum power to be used continuously in a light hull. The single engine is so narrow that, when enclosed, broad passages are left on each side to connect the forward and after cabins and compartments. In smaller boats, a single boiler is placed below decks. In large, shallow steamers, like those used on the Hudson River, the boilers are placed on the guards. In steamers admitting greater draught, like those used on Long Island Sound, the boilers are placed either on the guards or in the hold. Blowers are generally used to hasten combustion or to permit the use of anthracite pea coal. Some of the larger steamers of later construction have sufficient boiler power with natural draft. Boats making short trips on bays connected with the sea, carry fresh water in tanks for use in the boiler. Those making longer runs, often have surface condensers.

Steamers of this kind are adapted for use on routes along the sea coast and up navigable rivers by simply increasing the depth of hold, and sometimes dispensing with the guards, the freight being stowed below the main deck. The upper cabins are modified according to the average exposure during the sea voyage. Light draft propellers of similar construction are also used on this duty. Propellers are principally used on the great lakes, some being of large size; the draft, however, is restricted to about 14 feet, to pass the flats at Lake St. Clair. Propellers of this kind are used to tow one to four or more barges or schooners loaded with freight.

On the Mississippi river and its network of connecting rivers and

bayous, the steamers are of very peculiar construction. The fluctuations in the depth of water on the bars require very light draft, measured, for many streams, by inches, instead of feet. The hulls are shallow with flat bottoms, the ends sharpened more or less, but generally shaped to throw the water beneath. The main deck receives the machinery and freight, and supported by posts at a considerable distance above it are a series of cabins, reducing in size as they rise, till the "Texas" and pilot house tower over all, just behind two high smoke pipes, from which, when in use, black smoke, and sometimes flame, belch forth; the general appearance, together with the noise of the exhaust steam from the high-pressure engines, makes a lasting impression on the memory. The machinery consists of two horizontal engines, connected one to each side-wheel, or each to a crank at each side of a stern-wheel. The steam cylinders are long and of comparatively small diameter; the bed-plates are wood; the connecting rods or pitmans, of wood strapped with iron; the whole stretched out to distribute the weight as much as possible, and yet located at the sides, so as to be out of the way. The independent arrangement of the two engines enables the pilot to manœuver the boat by the wheels, even more than by the rudder. The steam pressure carried is usually about 150 pounds per square inch. The steam cylinders are fitted with single poppet valves and steam is cut off by a cam, at about half stroke. The feed water is heated by the exhaust steam. The boilers are cylindrical, set in brick work; they are externally fired, and the products of combustion return through two flues in each. Yet these apparently crude constructions have, by years of experience, been found best adapted for navigation in the shallow western rivers containing much sediment. Tubular boilers could not be made to stand, and iron framing or more condensed machinery would strain the boat or increase the dead weight and draft of water.

The cabins of passenger boats are well fitted up and are airy and comfortable, and the steamers do continuous satisfactory work in locations where it would be impossible to operate craft of more elaborate design. Some boats, of from 1 200 to 2 400 tons, "stern-wheelers," run between Cincinnati and St. Louis and New Orleans exclusively as freight boats.

Tow boats, which are all of the stern-wheel class, are 160 to 240 feet long, 30 to 40 feet beam, and draw $3\frac{1}{2}$ to 8 feet water. They carry only fuel, and are provided with powerful machinery. They are largely used

in transporting coal from Pittsburgh, &c., to New Orleans in barges carrying from 480 to 900 tons. These barges are *pushed* in front of the tow-boat. The *Ajax*, in this manner, took 22 500 tons from Louisville to New Orleans. The cost of transportation is 80 cents per ton from Pittsburgh to New Orleans, 2 000 miles, or $\frac{1}{100}$ of a cent. per ton per mile. Grain and other merchandise is also carried in the same way.

Steam is used regularly on the large canals, such as those connecting the Chesapeake and Delaware bays and the seaboard, the vessels being light-draft propellers with elevated cabins. The enormous traffic of the Erie and others of the long canals is as yet mostly carried in boats towed by horses and managed by companies and individual owners. Steam is, however, being introduced; the tug-boat consort and cable systems each having its advocates. Single steamers are also used to a limited extent, but are generally not considered advantageous, as the size of the hulls is restricted by the locks. The boats to and from the Erie Canal are towed on the Hudson River between New York and Albany, in fleets of 20 to 30 or upwards, by large side-wheel steamers specially adapted for the purpose.

On the lower Hudson are quite a number of propeller lines. The boats are arranged to carry freight on the lower deck, and cabins are provided above for passengers. These steamers tow barges with hulls of somewhat similar construction when greater capacity is required.

The ferry-boats on the eastern navigable rivers are a modification of the steamers. The boats are short and broad, and receive horses, vehicles, and passengers from the shore directly on the ends of the main deck, which is widened for the purpose by extending the guards. When being loaded, each boat is moored, end on, to a bridge with one end carried on a float and the other pivoted to the shore. The boats run either way, and are guided to place by pile buffers lining the slip, Passenger cabins are located at the sides on the guards, and occasionally an upper cabin is added. These steamers are made sufficiently strong and powerful to keep up communication through the ice in the hardest winters. On western rivers the ferry-boats are more like the ordinary steamers, and run only one way, as they need to head up against the current and land broadside to floats which are connected by bridges to the landings. Special ferry-boats are in use for carrying whole trains of railroad cars, and floats carrying eight to ten freight cars are towed from the termini of the lines to

freight depots at different portions of the water fronts of the cities, where the cars are often loaded and unloaded afloat.

SUBJECTS EXHIBITED.

25. *Drawing showing lines and construction of light draft stern wheel steamboat.*

This boat is of a class in very common use on the tributaries of the Mississippi. Though somewhat crude in design, it is the typical light-draft American river steamer. The drawing shows only the hull, but the arrangement of the upper works and the cabin is shown in the collection of photographs. Boats of this class carry nothing in the hold.

26. *Collection of photographs of typical stern wheel and other Mississippi river steamboats.*

27 *and* 28. *Drawings and photographs showing construction of ferry-boat and arrangement of ferry slips and bridges of the Erie Railroad Ferry at New York. Contributed by* O. CHANUTE, Chief Engineer.

The general arrangement of American steam ferries as conducted in the vicinity of New York, and on many tidal rivers in the United States and Canada, dates back to the very beginning of steam navigation, and was designed by Robert Fulton himself, in 1809, or soon after the trial trip of the "Clermont" to Albany, in 1807, had established the success of his application of the steam engine to navigation.

Almost the first use of this invention to which Fulton turned his attention, was the establishment of a steam ferry across the Hudson river, between the city of New York and the Jersey shore. He applied for a ferry lease and license in July, 1809, but a competitor having arisen in the person of Mr. John Stevens, who owned the shore line at Hoboken, and the barge ferry to that point, and who had been engaged with experiments in steam navigation since 1803, some delay resulted in settling their conflicting claims.

Leases were finally executed in March, 1811, to Fulton and his associates, under the name of the Jersey Association, for a steam ferry from the lower part of the city of New York to "Paulus Hook," on the Jersey shore (this being the local name of a projecting point of land near the southern limits of Jersey City), and to John Stevens, for a steam ferry from New York to Hoboken, near the northern limits of Jersey City.

Stevens succeeded in being the first to bring his line into operation, and in the early part of October, 1811, began running the first steam ferry-boat which plied in any part of the world.

Fulton started the first boat upon the "Paulus Hook" line in August, 1812, and the second in the following year. He obtained a ferry license across the East River, from Burling Slip, in New York, to the Fly Market, in Brooklyn, in 1813; and his general arrangement of ferry has continued in successful use ever since, with but trifling alterations.

The system was so thoroughly worked out in the beginning, that Fulton's own account of his design will stand fairly well for a description of the ferries of the present day, and the following letter, written by him to Dr. David Hosack, describing the boat, &c., which he had put into operation in 1812 upon the "Paulus Hook" line, will, doubtless, prove interesting:

Account of the Powles Hook steam ferry boat, in a letter to Dr. David Hosack, from Robert Fulton, Esq., Fellow of the American Philosophical Society, &c. (See Plate LI.)

"Sir,—At your request, I have sent you a bird's eye and side view of the Powles Hook steam ferry-boat and floating bridge, by which everything enters or is landed from her.

"My reasons for her particular form and arrangement of machinery are as follows:

"1st. She is built of two boats, each 10 feet beam, 80 feet long, and 5 feet deep in the hold; which boats are distant from each other 10 feet, confined with strong transverse beams, knees, and diagonal braces—forming a deck 30 feet wide, 80 feet long. To give her more strength, she is held together by four-inch braces, each two inches square, which pass through her one foot above the water line, and key on strong plates on the inside of each boat. Reflecting on a steam ferry-boat for Hudson's river, the waves usually running up or down, I found a great breadth of beam absolutely necessary to prevent the boat rolling in the trough of the sea. This is attained by two boats and one space, giving 30 feet beam.

"2d. By placing the propelling water-wheel between the boats, it is guarded from injury by ice or shocks on approaching the wharf or entering the docks, which operation being performed twenty-four times in twelve hours, allows no time for fending off with boathooks.

"To give despatch and convenience, it is necessary the boat should arrive at the bridge without the possibility of any injury; hence all important parts of the machinery should be carefully guarded, particularly the propelling wheels.

3d. The whole of the machinery being placed between two boats, on the beams over the open space, leaves 10 feet wide on each side, on the

decks of each boat for carriages, horses, cattle, &c. ; the other having neat benches, and covered with an awning, is for passengers. On the latter side there is a passage and stairs to a neat cabin, which is 50 feet long and 5 feet clear from the floor to the beams, and furnished with benches for passengers in rainy or bad weather. In the winter there will be a stove in this cabin, which will add much to the comfort of the passengers while navigating through the ice.

"4th. Although the two boats and space between them give 30 feet beam and proportionate stability, yet they present sharp bows to the water, and have only the resistance in water of one boat of 20 feet beam, which diminution of resistance gives speed in crossing,

"5th. The space from "stem to stern," that is, from *A A* to *B B*, of each boat. is 20 feet wide, which gives ample room at each end for carriages or persons to enter or go out of the boat.

"6th. Both ends being alike, and each having a rudder, she never puts about. At New York the horses and carriages enter at one end of the boat, the horse's head towards Jersey. On arriving they go out at the other end, without changing the line of direction ; in like manner, when coming from Jersey to New York. Thus the shortest possible and quickest movement of all that is to pass, is made to save time and secure convenience. Her rudders, which are placed as at *C C*, are equipollent—the iron shaft which serves as a rudder-post standing in the middle of each, as at *D*, by which construction, the pressure of the water being equal on each side of the centre, it can go either end foremost. With yokes and parallel bars, the movement of the rudders are carried to the helms at *E E*, the only position where the helmsman can have a full view of all around the boat, and see how to steer her into dock.

"It was at one time my intention to put a rudder on the bow of each boat, and work them by a connecting bar ; but considering that such rudders, while acting as bow, would be injured by ice or destroyed by shocks against a wharf or timbers, and knowing that the greatest current of water is exactly behind the wheel and between the two boats, I placed them as delineated, where they answer every desired purpose and are guarded from injury. In my first sketches I had made the inside line of each boat straight, that the water might have a free passage from one end to the other ; but the disadvantage of such a mode of construction would be, that the whole of the inside lines would act as lee-boards, rendering it difficult to put her about or to work her up in the tide. Had this boat been moved by wind, such a form, to prevent lee-way, would have been advantageous ; but moved by steam, the less water she draws, the easier she moves over it in every direction the better, her bottoms are, therefore, made rounding, with very little dead rise. Another material error which would have arisen from straight insides, would be that each bearing but half a boat, the two could not give more breadth of beam or so much buoyancy as one of the present boats ; and

to give the 30 feet beam it would be necessary to have a vacant space between the two insides of 20 feet, which long and hollow bearing would produce weakness. Such a boat, to carry the same weight, would draw near twice as much water as the present steamboats, and create a resistance in the water equal to the present resistance by breadth of beam.

7th. *F* represents the floating bridges, of which there is one on each side of the river.

G is a coffer, twenty-four feet long, twelve wide, and four deep, which gives a superficies of two hundred and eighty-eight feet, or nine tons weight to press it in the water one foot, or one thousand five hundred pounds to press it in the water one inch. This great resistance gives stability while carriages or heavy wagons enter the boat. The bridge is thirty feet long, twenty wide, fastened by four strong hinges to the coffer at *H*, and to the wharf at *I;* thus the bridge rests and falls with the tide, and is always exactly even with the end of the boat. When low water there is an easy descent into the boat; at half flood, the boat, bridge and wharf are on a level; at high water there is any easy descent from the boat to the wharf. As the weight of the bridge is on one edge of the coffer at *H*, to prevent its sinking on that side and rising on the other, a chain is fastened to the bridge, which passes over the pulley *J*, with a heavy weight *K*. Such an application on each side of the bridge pulls it up in the middle, and pushes down the coffer at *L*, added to which, a pine log, one foot square, is bolted on each side of the coffer, as at *M*, with two transverse logs dovetailed into them, of which the weight and leverage retain the coffer in a horizontal position. The next and last thing to be discovered, was how to make the boat arrive at the bridge without the aid of boat hooks, or any pushing or pulling or loss of time or shock, the latter being the most material to guard against; for this purpose the dock which receives her is one hundred and eighty feet long, seventy wide; the bridge is fastened to the middle of the bulkhead. The boat being only thirty feet wide, and the dock seventy, leaves twenty feet vacant on each of her sides; in these, twenty feet spaces, and on the water there are floating stages made of pine logs, which lie parallel to the boat for thirty feet and then run diagonally to the extreme end of the wharves, so that the boat, when coming in, hits within the seventy feet, and the stages guide her direct to the bridge. The stages are indicated *N. N.* To prevent shocks, there are two pieces of timber, each eight inches square, as at *O*, which move on rollers, and run out between the bridge and coffer; the two are connected by a crossbar *P*, and under the bridge by another crossbar *Q*. To this latter crossbar, and on each side of the bridge, there are ropes fastened, which ropes pass under pulleys at *S*, descend and fasten to buckets at *T*, which buckets of oak, strongly hooped with iron, are fifteen inches in diameter, six feet long, and when full of water will weigh about one thousand eight hundred pounds.

When the fenders *O* are projected to the position delineated, which is

about ten feet from the bridge, the buckets are down in the water, leaving their upper rim about three inches above the surface. *W* is the weight of the buckets, which drives the fenders out of their present position. Each bucket has four holes in the bottom, of an inch diameter, by which the water enters as they descend, and which lets out the water as they rise. In case the resistance should be too great for the boat to come close to the bridge, the water running out of the buckets will diminish it and let the boat arrive at the position required. To prevent shock the whole force must be gradually diminished to annihilation ; the resistance to the boat must be little in the commencement and increase until the whole power is destroyed. Fortunately this contrivance produces the desired effect. When the buckets are in the water, they are nearly buoyant; but the moment the boat strikes the crossbar *P*, and it begins to run in, the buckets come gradually out of water, and grow heavier each inch they rise, increasing resistance until the momentum is destroyed, and the boat arrives at the bridge without shock, when the passengers, carriages and, horses immediately move out, and others enter.

In the present state of this part of the machinery, to prevent shocks, it is necessary the men should be attentive to stop the engine in time. The most perfect machinery is that which leaves as little as possible to the care of man.

I have some additions to make which will prevent the possibility of shocks, even in cases where men may mistake or be careless. In a new combination of this kind, it is not to be expected that everything should work to the best advantage in a first experiment, or that every requisite should be foreseen. The boat which I am now constructing will have some important improvements, particularly in the power of the engine, to overcome strong ebb tides, from which again other improvements will be made. as in all other new inventions. The present boat crosses the river in a calm in fourteen minutes; her average time is twenty minutes.

She has had in her at one time, eight four-wheeled carriages, twenty-nine horses, and one hundred persons, and could have taken three hundred persons more. From the success of this experiment there is the pleasing prospect that boats of this kind will facilitate the passage of many of our wide rivers and bays, and prove an important benefit to our country.

I am, sir, respectfully,

Your most obedient,

ROBERT FULTON."

The mode in which the boats cross the river causes the chief peculiarities of the system. While, upon the steam ferries in use in other countries, the boats generally land with their sides against the shore, thus compelling a half turn at least with every crossing of the water, in the Fulton, or American system, they ply like shuttles between the shores, and are loaded and unloaded from the ends, instead of from the

sides. Thus the boats cross the river without turning, and effect a material saving of time. besides adding to the convenience in loading and unloading.

Beyond a general increase in size. but few changes have been made in Fulton's original design. Single hulls were substituted for the arrangement of double boats in 1836, and have been preferred ever since. The docks or slips have been enclosed with spring piles, itstead of the floating stages, and the ingenious buffer of Fulton has been dispensed with ; india rubber springs at the hinge of the floating bridges being substituted, while the boats are slowed upon their entrance into the slips by reversing their paddle wheels.

For ease in loading and unloading, rapidity in crossing, comfort of passengers, and cheapness of charges, this system is believed to be superior to that in use in any other part of the world.

The particular ferry selected for illustration is that of the Erie Railway. This consists of two lines from the terminus at Jersey City; one to the lower portion of the City of New York, a distance of $1\frac{1}{10}$ miles, and the other to the upper portion of that city, a little over 2 miles. These are served by four ferry boats, which make 4 trips or crossings per hour upon the lower, and 2 per hour upon the upper line. Thus they maintain a speed of about 4 miles per hour, *including the time stopping and starting and that spent in their docks.* This is generally about five minutes on the lower line, and is found amply sufficient to unload and reload 400 or 500 foot passengers, and 10 to 20 carriages.

The "Susquehanna" (the boat illustrated) is a fair representative of the line. She is of 921 tons burden, with 692 nominal horse power, and is licensed to carry 600 foot passengers, and 25 two-horse wagons) or as alternative 20 coaches, or 16 double teams.

Her cabins are lighted with gas, and warmed by steam, and provide seats for 266 passengers.

The ferriage charge is 3 cents per footman upon either line, thus being at an average rate of about 2 cents per passenger per mile.

The docks or slips into which these ferry boats run, are generally about 180 feet long, and about 90 feet wide, being curved as shown on the plans, to correspond with the shape of the boat. They are lined with spring piles, driven into the mud, which yield and spring back when struck by a boat in entering or leaving. The better to enable the latter to glance off, on such occasions, their guards are shod with iron, and slushed with some cheap grease.

In some American rivers of greater rise and fall than 5 feet, this being the mean tides in the vicinity of New York, the approaches have been made upon a series of several floating bridges, hinged end to end, and supported at their junction upon pontoons, which ground successively upon submerged piers, so as to present nearly the same inclination of roadway, at the several stages of the tide.

29. *Photographs showing interior of cabin and outside view of Mississippi river steamboat "Grand Republic." Also a photograph of a St. Louis ferry-boat which is typical of the ferry-boats used on the Mississippi and its tributaries.*

The " Grand Republic " was one of the largest and finest passenger steamers on the Mississippi river. She ran between St. Louis and New Orleans, a distance of 1 200 miles. She was one of the few Mississippi river boats provided with compound engines.

The general design of the St. Louis ferry-boat is that of two hulls with a single bow; the engine is placed in the centre, the wheel working between the hulls, and the cabin is overhead. The entire main deck, except the part occupied by the machinery and boilers is left open, and forms a standing place for teams and animals which may be driven completely around the boat. The boat lands against a float moored to the shore, and teams drive on at the side.

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30. *Engine of steamer "City of New York." Also photographs of steamers "Bristol," "Sunnyside," and "Massachusetts."*

The steamers " City of New York " and "City of Boston" were built in 1860, for the passenger and freight business between the cities of New York and New London (distance 120 miles), connecting at the latter place with railroad lines for the cities of Worcester and Boston, and other points in the interior of New England ; one of these steamers leaving either terminus of the route every evening except Sunday.

Their hulls were constructed in the best manner by Samuel Sneden, from specifications of Charles W. Copeland, the superintending engineer for the steamboat company. They are not only timbered and fastened in the best manner, but have in addition, very strong hog or truss frames, well secured by iron straps and bolts, also upon the frame of the hull diagonal iron strapping of flat bar iron fitted and fastened in the manner usual in the construction of seagoing steamers, the upper end of the diagonal straps being riveted to a longitudinal iron bar 6 inches wide, which is run around the entire length of the vessel, just below the deck beams, and the lower ends terminating some distance below the floor heads. These diagonal bars are rivetted at every crossing and bolted into every timber.

For the accommodation of passengers, there are 82 private state rooms and 269 berths. The cabins and state rooms are heated by steam, which is supplied by a small boiler provided for that and other purposes, when the main boilers are not under steam.

There is an ample provision of steam and hand pumps, and other fire apparatus, ready to be brought into use in case of necessity.

These steamers are 305 feet in length, 38 feet 8 inches beam, and 12 feet 4 inches hold.

Their engines are condensing engines, and have cylinders 80 inches diameter and 12 feet length of stroke, of the lever beam type, with double or balanced poppet valves, having "Stevens" cut-off motion for working steam expansively. They have also "Sickel's" patent heart-motion with counterbalance weight, to enable the engine to be worked with ease and facility by one person.

The boilers are of the return-tubular type; the fuel used is anthracite coal, and the combustion is forced when necessary, by the use of Dempfel's patent fan blowers.

The engines and boilers were constructed by the Novelty Iron Works from the specification and drawings furnished by Charles W. Copeland. Their easy and quiet operation and economy, as well as the speed of the vessels, have been all that could have been expected, and in these respects, are not excelled by any steamers of their class.

Their paddle-wheels are 38 feet 8 inches diameter, 9 feet 8 inches length of bucket, and 28 inches width of bucket. The maximum speed of engine 19½ revolutions per minute, the average being about 17.

The average consumption of coal during the first two years of their running was seventeen tons a passage, but owing to their increased weight, by additions and other causes, the average consumption is now about nineteen tons a passage.

These steamers carry full loads of passengers and usually from 250 to 300 tons of freight.

Photographs of the exterior and interior of the steamer "Massachusetts."

The steamer "Massachusetts" was launched September, 1876, and commenced running May 7th. 1877. She was built at Greenpoint, Long Island, and the launching weight, without machinery or joiner-work, was 1 000 tons. She is 3 500 tons burden, 350 feet long, 80 feet breadth, and 16 feet depth of hold.

Her frames are of white oak, locust and cedar. Floor timbers of white oak throughout, sided, 9 inches; moulded 18 inches. Spaces between frames filled in solid, up to turn of bilge. Top timbers of locust and cedar; sided 7 inches. Main keelson and sister keelsons, nine in number, of Georgia pine, 13 by 26 inches. In addition, there are two bilge keelsons of same material, 14 inches deep. These keelsons extend entire length of vessel. The engine keelsons are of white oak and Georgia pine; length 60 feet, by 5 feet 3 inches in depth; width, 3 feet. Bilge strakes are ten in number, 9 by 11 inches, of Georgia pine. Ceiling and clamps are 6 inches thick, of Georgia pine. Deck beams of white pine, 8 by 8, to 15 by 18 inches. Deck of white pine, 3½ inches.

The frames of hull are diagonally strapped with iron bars, 4 by ¾ inches; spaced 4 feet. The planking is of white oak; the bottom 3½ inches, the sides and tops 4 inches. The strings are of Georgia pine, 6 inches thick, three strakes in depth. The masts are five in number, 67 feet high, 18 inches in diameter; connected to each other and to the hull with stays of iron 2 inches in diameter. The truss or "hog" frame, is 40 feet high above main deck, extending the entire length of vessel; the timbers composing the same of unusual strength. The iron rods and straps combining the frame with the hull, are in proportion with the timber. The guards are protected below with lattice sponsons.

There is a grand saloon or state-room hall, arranged with gallery and second tier of rooms. There are two hundred rooms, each accommodating two persons; there are a number of large rooms. There are two hundred and twenty berths for first-class passengers. There are electric bells in each room, connecting with the steward's department. The rooms are carpeted with Wilton, Axminster and velvet; furnished with black walnut bedsteads, hair mattresses, and are excellent in every appointment. The steamer is lighted throughout (including rooms) by gas, and is heated by steam. The dining room is on the main deck. It is free from all sleeping apartments and the foul air of lower cabins. About three hundred and eighty thousand feet of lumber was used in constructing the joiner work.

The machinery is an engine of the vertical beam type, with a cylinder of 90 inches diameter, and stroke of 14 feet.

The wheels are 39 feet 7 inches diameter.

The engine is fitted with the Sickel's adjustable valve gear and a tubular surface condenser, with Lighthall's patent tube heads and tube packings. The refrigerating water is circulated by means of an independent centrifugal pump, capable of moving 6'000 gallons of water per minute. The same pump is fitted with appliances by means of which the whole capacity could be used in freeing the vessel from water in case of severe leakage.

The boilers are tubular, six in number, of steel. They are circular, 12 feet 8 inches in diameter, and each has three circular furnaces 3 feet 4 inches diameter. The boilers are placed thwartship of the vessel, in the hold, with fire-room between, fore and aft. The boilers are connected to two independent steam "drums" or chimneys, each boiler having a separate shut-off valve, which admits of their use together or separately. The smoke pipes, two in number, are 8 feet in diameter, placed "fore and aft." In addition to the ordinary steam and hand pumps for extinguishing fire, steam pipes are run to all parts of the vessel, so that by the simple turn of a valve, always under the control of the engineer, a fire can be extinguished before it has fairly started. The engine is capable of making twenty-four revolutions per minute; and when making only twenty per minute she acquires a speed of 19½ miles an hour.

The steamer "Rhode Island" is similar in style and finish, and has all the improvements of the steamer "Massachusetts." She is the fastest steamer leaving New York, and can run twenty-two miles per hour.

Both of these steamers are steered by steam, having separate engines for the purpose.

The cost of these steamers—"Massachusetts" and "Rhode Island" ready for service, was $500 000 each, viz. :

Hull	$120 000
Machinery and boilers	180 000
Joiner work	90 000
Furniture and equipments	110 000

They are manned by a crew of ninety men, viz. :

Deck department	26
Engineers' department	30
Stewards' "	34

The "Massachusetts" and "Rhode Island" are owned by the Providence & Stonington Steamship Company, which operates two lines between New York City and New England, which are known as the Providence Line and the Stonington Line.

The route of the Providence Line, which was first established in 1822, is from New York City to Providence, Rhode Island, by water, a distance of 184½ miles ; thence by rail to Boston, Massachusetts, a distance of 42 miles.

The Stonington Line, established 1836, is between New York and the East, the boats running to Stonington, Connecticut, a distance of 120 miles.

There were carried last season upon the steamers of the Providence Line, from May 7th to October 4th over 86 000 passengers and 224 250 tons of freight. The Stonington Line steamers carried 56 270 passengers and 327 130 tons of freight.

RAILROAD ROLLING STOCK.

In no department do American railroads differ more from those of Europe than in the rolling stock which runs upon them. Originally of cheap and inferior construction, with sharp curves and irregularities of surface, these railroads demanded rolling stock of more flexible character than was needed on the more expensive roads of Europe.

In the construction of cars, this object was accomplished by the use of the independent truck; which enabled long cars to pass without difficulty around very sharp curves, and accommodated itself to the irregularities of the track, transmitting to the body of the car simply the resultant of the movements as felt at the centre, where the connection is made with the pin. This truck system is in universal use; the details of the different trucks differ materially, some being largely of wood, and others almost entirely of iron; but the one principle which is everywhere followed is to hang the long body of the car on two independent trucks, which are free to rotate on pins, and which follow the curve of the track, while the body of the car takes the position of a chord. The only exceptions are in short cars used for coal, and other heavy freights, which have but four wheels, and a few larger coal cars of peculiar design in which the axles are kept parallel, but free to move transversely for a moderate distance.

American railroad cars may be grouped under the two general classes of passenger train equipment and freight train equipment.

The passenger train equipment includes besides the coaches in which passengers ride, the baggage, mail and express cars, which are carried on the same train. An express train on a long line is usually made up in the following manner : a mail car, placed next to the engine, and provided with all arrangements for distributing mails, and for receiving and delivering mail bags at stations where the trains do not stop ; an express car used exclusively for express freight ; a baggage car for the baggage of passengers on the train ; two or more day passenger coaches, each seating about 54 people ; one or more sleeping cars. On some of the less important lines, a single car, divided into compartments, is made to answer for mail, baggage, and express, while on the other hand, on many railroads much longer trains are required. A fully equipped first-class passenger train is illustrated by the photographs of a train on the Pennsylvania Railroad, with a description of each class of cars.

The principal varieties of freight cars in use are : the flat car, a single uncovered platform ; the box car, a house car with doors on the sides ; the stock car, with tight roof, but sides made with open slats, for carrying cattle ; the oil car, which consists of a platform carrying an air tight boiler shaped tank of iron ; and the coal car, of which there is a great variety of patterns. All of these cars, except the coal cars, are built with two trucks and eight-wheels of chilled cast iron, and measure about 30 feet in length as they stand in a train. For grain and general merchandise the eight wheel box car is universally used ; these cars weigh from 17 000 to 20 000 pounds, and carry from 22 000 to 28 000 pounds. A freight train is made up of freight cars of different varieties, to which is always added at the rear a "caboose," which is a small car of plain construction, in which the tools, lamps and outfit of the crew are carried, and which is the headquarters of the conductor of the train.

The standard American locomotive for both passenger and freight traffic is the eight-wheel engine. The first engine of this class is said to have been designed by Mr. Henry R. Campbell, of Philadelphia, in 1836, though the "equalizing beams" by which the weight is distributed on the driving wheels were introduced somewhat later by Mr. Joseph Harrison, Jr. The forward end of the engine rests on a four-wheel truck which carries about one-third of the whole weight, the other two-thirds being equalized on two pairs of driving wheels. In 1851 this class of locomotives had substantially its present appearance, but was different in many details. It was then usual to make the locomotives with cranks

and inside cylinders, and the reversing of the valve was accomplished with the so-called hook motion. About the year 1855, outside cylinders and the shifting link valve motion came into use.

The earlier locomotives with outside cylinders had a rectangular smoke box and the cylinders were bolted to it; this arrangement answered very well so long as the locomotives were small, but as their size increased it became customary to make the smoke box round and to fasten the cylinders to a large casting called the saddle, upon which it rested; this was a decided improvement, but not so good as the present practice of casting one-half of the saddle with each cylinder, the two cylinders being of the same shape and interchangeable.

For switching cars in yards small locomotives, the whole weight of which is carried on two or sometimes three pairs of driving wheels, are commonly used; they are often built with tanks over the boiler, so as to dispense with tenders, but this practice is by no means universal.

Upon railroads where locomotives of greater power than the standard eight-wheel engine are required, the practice was formerly to use a "ten-wheeler," the peculiarity of which was that it had three pairs of driving wheels instead of two, the other features of the eight-wheel engine being retained. On the Baltimore & Ohio Railroad, a locomotive of peculiar construction, known as a "camel" has long been in use; the entire weight is carried on four pairs of driving wheels; the cylinders are outside connecting with the third pair of wheels and the cab is placed on top of the boiler, directly behind the smoke stack, giving the engine a singularly ungainly look. But the two classes of locomotives which are now generally preferred for heavy freight traffic, especially on heavy gradients, are the "Mogul" and the "Consolidation" engines, both of which are fully illustrated in the Society's exhibit.

The "Mogul" has three pairs of driving wheels connected and a two-wheel swing truck in front, equalized with the front driving wheels. It has rapidly grown in favor for freight service on heavy grades or where maximum loads are to be moved, and has been adopted by several leading lines. Utilizing, as it does, nearly the entire weight of the engine for adhesion, the main and back pairs of driving wheels being equalized together, as also the front driving wheels and the pony wheels, and the construction of the engine, with swing truck and one pair of driving wheels without flanges, allowing it to pass short curves without difficulty, the "Mogul" is generally accepted as a type of engine especially adapted to the economical working of heavy freight traffic.

The original engine named the "Consolidation" was built in 1866 to operate a grade of one in forty on the Lehigh Valley Railroad; it had cylinders twenty by twenty-four inches, four pairs of driving wheels, connected, forty-eight inches in diameter, and a two-wheel swing truck in front, equalized with the front driving wheels. The weight of the engine, in working order, was ninety thousand pounds, of which all but about ten thousand pounds was on the driving wheels. This engine was the first of a class to which it has given its name, and which are now recognized as the most powerful freight engines in use.

SUBJECTS EXHIBITED.

31. *Photograph of locomotive and of coal chute bridge in use on Philadelphia, Wilmington & Baltimore Railroad. Designed by* S. T. Fuller, C. E.

This bridge, which is of iron, placed over the four tracks, has a clear height above same of 18 feet and a clear width of 16 feet, on which is laid a track of 3 feet gauge for the dump cars. On the side of the railroad, at end of and grade of "coaling bridge," is a storehouse, capable of holding 800 tons of coal. This storehouse is reached by a track about 1 000 feet long, extending from grade of railroad along the top of slope, over which the coal is taken in ordinary cars, the grade of track in storehouse allowing the coal to be dumped through the bottom of the cars. Tracks and turn-tables are provided to allow the coal to be loaded into cars holding one ton, and in any part of the storehouse, and moved by hand, passing over a scale to the chutes on coaling bridge. These chutes are of wrought iron, 18" x 24", 9 feet long, and are hung to a shaft on under side of bridge, the shaft passing through the upper side of the chute, so that their lower ends, when in position, will be in centre of track. They are balanced by a movable weight on the end of an attached lever, so that they will, when not in use, hang up under the bridge. An engine is coaled in from one-half minute to a minute and a half, without dust.

The second photograph shows the same general arrangement, except that the coal is raised vertically by steam power after being loaded in small cars, the storehouse being at grade of railroad; and there are two chutes on each shaft, which allows two cars to be dumped at once, and at different places in the tender.

32. *Detail Drawing of Sleeping Car. Built by* Messrs. Gilbert, Bush & Co.

33 and 34. *Photograph and Detail Drawing of Consolidation Locomotive. Built for Erie Railway by* BROOKS LOCOMOTIVE WORKS, *according to following Specification.*

Dimensions.—Cylinders, 20" dia. and 24" stroke. Drivers, 50" dia. outside of tires. Gauge, 4 ft. 8½ inches. Fuel, anthracite coal. Total wheel base of engine, 22' 10". Driving wheel base, 14' 9". Weight in working order—total—about 100,000 lbs. Weight on drivers, about 88,000 lbs.

Boiler—Made throughout of best quality of Otis steel $\frac{7}{16}$" thick, Riveted with $\frac{13}{16}$" rivets placed not over 2¼" apart from centre to centre. All horizontal seams to be double riveted ; all parts well and thoroughly stayed, and extra welt pieces riveted to inside of side sheets. providing double thickness of metal for studs of expansion braces. All seams to be properly caulked. Boiler tested to 180 lbs. pressure per square inch.

Waist.—54" dia. at smoke box ends ; made telescopic and with one dome placed over fire box—double flanged—smoke box of ½" iron.

Tubes—Of iron, No. 13 W. G., 200 in number, 2" outside diameter, and 135½ inches in length between tube plates, 2⅝ inch centres of tubes.

Furnace—Of best quality Otis steel, 123 inches long and 33⅜ inches wide inside of mud ring, and 44 to 56¾ inches deep from bottom of mud ring to under side of crown sheet (front and back ends), all plates to be thoroughly annealed after flanging ; side and back sheets $\frac{5}{16}$ inches thick, crown sheet ⅜ inch thick, flue sheets ½ inch thick, water space 3 inches at sides and back, increasing in width at top, water space in front 4 inches ; stay bolts, made of best Ulster iron, ⅞ inch dia., screwed and riveted to sheets, and not over 4½ inches apart from centre to centre.

Crown Bars—Crown sheet supported by crown bars, made of two pieces of wrought iron, each 4½"x⅝" section, set ⅞ inch above crown, placed $5\frac{1}{16}$ inches centres, and bearing on side sheets, crown stayed by braces to dome and outside shell of boiler.

Cleaning Holes.—Cleaning plugs in corners of firebox, and blow off cock in front.

Throttle Valve—Balance throttle valve of cast iron placed in dome.

Grates—Of iron tubes 2" outside dia. No. 4 W. G.

Ash Pans—With cast iron frames and slides.

Smoke Stack—Erie Railway standard.

Main Frame——Of best hammered iron made in three sections—main frames forged solid.

Front Rails.—Front rails bolted and keyed to main frames, and with front and back lugs forged on for cylinder connections.

Pedestals—Pedestals protected from wear of boxes by cast iron flanged wedges. Pedestal caps lugged and bolted to bottom rails of frame.

Truck.—Swinging, centre bearing, two wheeled truck, two double plate chilled wheels of approved make 30" diameter.

Axles--Of best hammered iron, with inside journals, 5" diameter and 10 inches long.

Springs—Of best cast steel, tempered in oil.

Cylinders—Of best close grained iron as hard as can be worked--each cylinder cast in one piece, with half saddle, placed horizontally: right and left hand cylinders reversible and interchangeable, accurately planed, fitted and bolted together. Oil valves placed in cab and connected to steam chests by pipes running under jackets. Pipes proved to 200 lbs. pressure.

Pistons—Heads and followers of cast iron, fitted with Dunbar packing. Piston rods of best hammered iron, ground and keyed to cross heads, and secured to piston head with brass nut.

Guide—Of wrought iron, case hardened, fitted to wrought iron guide yoke.

Crossheads—Of wrought iron, with wrist pin of wrought iron, case hardened.

Valve Motion.—Most approved shifting link motion, graduated to cut off equally at all points of stroke. Links, blocks, pins, lifting links and eccentric rod jaws made of the best hammered iron, well case hardened. Rocker shaft and reverse shaft of wrought iron, with arms forged on, except vertical arm of reverse shaft, which is to be keyed on.

Driving Wheels.—Eight in number, 50 inches in diameter, centres of cast iron, with hollow spokes and rim, and turned to 44 inches diameter to receive tires.

Tires—Of steel, 3 inches thick when finished, 3 pair flanged 5¾ inches wide, 1 pair plain 6" wide—the plain tire to be placed on the main wheels.

Axles—Of hammered iron, excepting main axle, which is to be of steel—journal 7" dia. and 8 inches long. Driving boxes of cast iron, with brass bearings.

Springs—Of best cast steel, tempered in oil.

Rods—Connecting and parallel rods of best hammered iron, forged solid, furnished with necessary straps, keys and brasses. Parallel rod brasses to be babbitted, the grooves for babbitt to run full length of bearings.

Crank Pins—Of hammered iron, except main pins which are to be of steel.

Feed—To be supplied by one injector and one pump, or two injectors, as directed.

Water—Guide yoke made with lugs for 2 pumps, in case they are required.

Cab—Substantially built of hard wood, well seasoned and finished, and fitted together with joint bolts and corner plates.

Pilot—Oak frame and ash slats.

Finish—Cylinders lagged with wood, and neatly cased with Russia

iron. Heads of cast iron, painted. Steam chests with cast iron tops, bodies cased with sheet iron. Dome lagged with wood, with sheet iron casing on body, and cast iron top and bottom rings. Boiler lagged with wood, neatly jacketed and secured by iron bands.

Furniture—Engine to be furnished with sand box, brackets and shelf to receive head lamp, bell, whistle, heater, blower and safety valve, steam gauge, cab lamp, gauge cocks, oil cans and tallow pot. Also a complete set of tools, consisting of two jack screws, one pinch bar, a complete set of wrenches to fit all bolts and nuts on engine, one monkey wrench, hammer, chisels, cab seat cushions, poker, scraper and slice bar.

Painting.—Engine and tender to be painted and varnished.

Gauges—General features of construction—all principal parts of engines accurately fitted to gauges and templates and thoroughly interchangeable.

Case Hardening—All finished movable nuts, and all wearing surfaces of machinery, to be of steel or wrought iron, case hardened.

Threads—To be United States standard, as designed by Wm. Sellers for Franklin Institute, of Philadelphia. Absolute accuracy in this insisted upon.

Tank—Tank strongly put together with angle iron corners, and well braced. To be made of $\frac{3}{16}$ iron, riveted with $\frac{3}{8}$ rivets. $1\frac{1}{4}$ inches pitch. Capacity 2,500 gallons.

Frame—Of wrought iron, as per tracing.

Truck—Of wrought iron frames, with wooden battens; chilled wheels, of approved make, 30 inches dia.; brakes on rear tender truck.

Axles—Of best hammered iron; outside journals $3\frac{1}{4}$ inches dia. and 7 inches long; oil tight boxes, with brass bearings.

Tool Boxes—Of hard wood, bound with iron—one box at back end of tender frame, and two boxes on top of tank.

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35. *Photograph and Detail Drawing of First-class Passenger Coach. Built by the* Wabash Railway Company.

Wabash Railway, Coach No. 6. Extreme length of car, including platform, 60 feet 5 inches. Width over all, 10 feet 4 inches. Outside height, 10 feet 4 inches. Car is furnished with Miller platform and wrought-iron drawbar. Has two six-wheel trucks. Extreme length of truck, 13 feet. Width, 6 feet $7\frac{1}{4}$ inches, with wheel centres 4 feet 8 inches apart.

Interior of car. Extreme inside length, 53 feet 3 inches. Inside width, 9 feet. Inside height, 9 feet 4 inches. Inside width of upper deck (monitor top), 4 feet 8 inches. Finished with white ash with black walnut trimming. Number of windows, 40, 18 on each side of car and

2 at each end. Door at each end of car. Car contains 15 double seats on a side, seating 60 people. Cushions upholstered with red plush, with green plush backs. Saloon at each end of car. Car is heated by two hot-air stoves.

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36. *Detail Drawing of Freight Locomotive. Mogul pattern, in use on Louisville & Nashville Railroad. Designed by* FRED. DE FUNIAK, C. E. and M. E.

The engine is outside connected and supported on eight wheels, three pairs of which are coupled driving wheels, one pair of them behind, and two pairs in front of the furnace. The front end of engine is supported by a single pair of truck wheels. Rigid wheel-base 15 feet. Total wheel base of engine 22 feet 4 inches.

Cylinders.

Are horizontal, 18 inches diameter, with 24 inches stroke of piston, and 84 inches apart from centre to centre; half the "saddle" or bed plate is cast on each cylinder.

Driving Wheels.

Of cast iron, with steel tires shrunk on. Rear and front pair with flanged tires 5½ inches wide. Middle pair with flat tires 6 inches wide. Diameter of drivers 54 inches.

Engine Frame.

Solid bar iron 3 × 4 inches with the pedestal jaws forged on. Front end of frame securely bolted to the cylinder bed or saddle.

Engine Truck.

Single pair of truck wheels 30 inches diameter in radiating frame, and connected by equalizing levers with the front drivers.

Boiler.

Straight on top, with one steam dome, Shell of boiler ⅜ iron. Smallest ring of waist 50 inches diameter. Furnace outside 5 feet 8 inches, by 5 feet 7½ inches. Fire box of steel 61½ inches by 36⅜ inches inside; tube sheet ⅜ inches, sides and crown-sheet $\frac{5}{16}$ inches. Tubes 170 of lap-welded C. C. iron 2 inches outside diameter by 11 feet 4 inches long with ⅝ inch water space between them.

Heating Surface.

In fire box	102	square feet.
" tubes	1020	" "
Total heating surface	1122	" "

Grate Bars.

Of cast iron, in pairs, have journals on ends and arranged for rocking motion. Amount of grate surface 15½ square feet.

Smoke Stack.

Of cast iron $\frac{5}{16}$ inch thick with a deflecting cone casting in top and spark arrester of No. 10 steel wire four meshes to inch across the top.

Valve Motion.

Slide valves of the "*D*" pattern, with $5\frac{1}{4}$ inch travel. Outside lap $\frac{3}{8}$ inch. Valves are connected to upper arms of rockers by valve stems, the lower arms of rockers are attached to the usual "shifting" links connected by eccentric rods to eccentrics on the main driving axle.

Tender.

On eight wheels 30 inches diameter. Capacity of tank 2 800 gallons; with space for 200 bushels of coal. Weight of tender empty 18 500 pounds.

Weight of Engine.

On driving wheels	66 000	pounds.
On truck wheels	14 000	"
Total weight in running order	80 000	"

NOTE.—There is no pump on engine, the feed water being supplied to boiler by two No. 7 improved injectors.

38. *Photographs of Locomotives, built by* DANFORTH LOCOMOTIVE & MACHINE COMPANY.

39. *Photograph of Snow Plow on Kansas Pacific Railway,*

40. *Detail Drawings of Freight Cars with iron trucks in use on the Chicago, Burlington & Quincy Railroad.*

Three patterns, viz., box cars for grain ; combination cars for cattle or goods and flat cars.

41. *Drawing of Iron Coal Car.*

The peculiarity of this car is the attachment of the axles to the body of the car; the attachment being made by side levers which are pivoted at the centre, thus allowing the axles to move transversely, but keeping them always parallel.

42. *Photographs and Drawings of Passenger and other Locomotives. Fireless locomotives in use in New Orleans.*

These fireless locomotives are used on street railways; they are charged with steam to a pressure of 120 pounds, and run two and a half miles and back, the steam pressure being reduced to 60 pounds at the end of the five mile trip.

Photographs of Locomotive and Passenger Train on the Pennsylvania Railroad. (See Plate LII.)

The train is composed of a Passenger Locomotive and nine cars. Westinghouse automatic air brake of the latest arrangements; there are also hand brakes acting independently of the air brakes. Janney Coupler, side buffers and platform recently adopted by the Pennsylvania Railroad.

Locomotive 64 is a Pennsylvania Railroad standard class "*C*," Locomotive for burning bituminous coal. The cylinders are 17 inches by 24 inches. The driving wheels are 62 inches in diameter. The boiler is of steel, and contains 155 iron tubes, 2 inches inside diameter, 128$\frac{1}{16}$ inches long. The fire grate area is 17.6 square feet, and total heating surface of tubes and fire-box 1056.98 square feet. The weight of the locomotive ready for the road is 75 500 pounds. The tender has a capacity of 2 400 gallons of water and 8 000 pounds of coal, and is fitted with water scoop for taking up water while running, for which purpose water troughs are located between the rails at certain points.

United States Postal Cars 24 and 25 (both alike), length 60 feet, width 8 feet 7 inches, height 9 feet 4 inches. The cars have doors at both ends and two double doors on each side; there are 11 windows on sides and 36 in upper deck. Each car contains the following furniture: Bin 22 feet 5 inches long, divided by upright posts into 5 compartments for storing pouches. Bin 16 feet 3 inches long divided by upright posts into 3 compartments for storing pouches. Two racks 16 feet long, 2 feet wide with hooks for hanging mail bags. One rack 5 feet 6 inches long, 3 feet wide with hooks for hanging mail bags. One table 2 feet 5 inches high, 26 inches wide, 17 feet 2 inches long, with mail boxes, drawers and closets underneath. One table 16 feet long, 2 feet 2 inches wide; one letter case on end table, containing 600 pigeon holes 4 inches by 4¼ inches. Two paper cases containing 16 pigeon holes each, eight being 10 inches wide and 21 inches deep; seven 12 inches wide and 21 inches deep, and one 12¾ inches by 21 inches deep. Besides the above mentioned furniture each car contains a water closet, Baker heater, wash stand, closet for clothes, water reservoir and the necessary lamps. The weight of these cars when empty is about 51 000 pounds each. The average weight of mail matter carried per records, is as follows:

General daily average for 70 days	9 862	pounds.
Daily average for highest 7 days	15 745	"
Maximum one day	18 537	"

The cars are carried on six wheeled trucks.

Express Car 46 is of the ordinary style used by the Pennsylvania Railroad. Length of body 40 feet 1½ inches; outside width 9 feet 4¼ inches; outside height, 8 feet 1 inch. Sliding doors on sides, 5 feet 6 inches wide, end platforms but no end doors, thus cutting off communication with the train in order to ensure safety of express matter; ventilators on sides but no windows. Hand brake can be applied as well from inside of car as from the end platforms. The weight of this car is about 30 000 pounds. The car is carried on four wheeled passenger car trucks, Pennsylvania Railroad standard.

Baggage car No. 70 is 40 feet 1½ inches long outside, 9 feet 4¼ inches wide outside, 8 feet 1 inch high outside; has side doors 5 feet 6 inches wide, end doors 2 feet 1 inch wide, and 2 windows on each side, also end platforms. Hand brake can be applied from inside of car. The weight of this car is about 30 400 pounds. The car is carried on four wheeled passenger car trucks, Pennsylvania Railroad Standard.

Passenger Cars 574 and 578 (both alike). The length of body is 46 feet 7 inches, outside; the width, at cornice, 9 feet 8 inches; 10 feet 8⅝ inches high. These cars will seat 54 passengers each. At one end of the car is a cabinet containing urinal and water-closet, also the water tank for ice water; on the outside of the cabinet is the water spigot and splash basin. There are fifteen windows on each side, two at each end, besides a glass panel in the doors; the upper deck has thirteen lights on each side; these latter are movable, so as to act as exhausting ventilators. The finish of the car is in maple, cherry and ash. The cars are carried on four-wheeled passenger car trucks. The weight of each car is about 39,000 pounds without passengers.

Pullman Palace Parlor Car, No, 209. The length of car is 58 feet 1 inch; width, at eaves, 9 feet 11 inches. It contains, in addition to the main compartment, two drawing-rooms, 6 feet 6 inches by 7 feet (seating five persons each). Total seating capacity, forty-four persons. The car is lighted by thirty-four windows on the sides, and twenty-four ventilators or deck sash openings. The trucks are of the six-wheeled patern used on Pennsylvania Railroad. The total weight of car, without passengers, is 54,000 pounds.

Pullman Palace Sleeping Car, No. 272. The length of car is 52 feet 2 inches; width, at eaves, 10 feet 0½ inches. The car contains, in addition to the main compartments, a state room 6 feet by 32 inches, seating four persons. Total seating capacity, fifty-four persons. The trucks are of the six-wheeled Pennsylvania Railroad pattern. The total weight of car, without passengers, is 54,000 pounds.

Pullman Palace Sleeping Car, No. 291. The car has a length of 56 feet; a width, at eaves, of 10 feet 1 inch. The main compartment seats forty-six persons, and the smoking room, 6 feet by 6 feet, four persons. The car is lighted by eight single and thirty double windows, and has thirty-four ventilators in deck, and end ventilation. The trucks are of the six-wheeled pattern. The total weight of the car, without passengers, is 55,000 pounds.

RIVERS AND HARBORS.

The river and harbor improvements in the United States have been, with very few exceptions, executed by the General Government. Previous to the late civil war quite a number of small works were undertaken, and also some of considerable importance. Among the more extensive earlier works was the Delaware Breakwater, a structure of considerable size and importance, as forming a harbor of refuge immediately north of Cape Henlopen, at the entrance to Delaware Bay. Another important improvement early discussed was the removal of the rocks at Hell Gate, in the easterly entrance to the New York harbor, which has been so successfully carried out within the past few years. Since the civil war the field of government improvements has been greatly enlarged, and there is scarcely a navigable stream in the country upon which some work has not been done in improving the channel. Almost every harbor on the coast has also been the subject of small annual appropriations to improve its entrance.

A very complete description of the Government works will be found in the Annual Reports of the Chief of Engineers United States Army, for the years from 1866 to 1876, inclusive. A general report of the works in progres up to that time was made in 1866, since which time the annual reports describe what has been done during each year. There are also many valuable reports relating to rivers and harbors among the professional papers of the Corps of Engineers. Among them is the Report upon the Physics and Hydraulics of the Mississippi River, by Generals Humphreys and Abbot.

Among the more important works now in progress are the New York Harbor Improvements, which embrace the removal of the remaining obstructions at Hell Gate, in the East river, by the United States; the construction of a permanent masonry wall, with projecting piers, around the city, the improvement of the channel of the Hudson river and connecting the Hudson and the lower Harlem river by a ship canal across Manhattan Island, thus opening navigation between the Hudson and the East river or entrance to Long Island Sound.

The most noted work now going on is, perhaps, the construction of the jetties at the mouth of the South Pass of the Mississippi river. This work has been vigorously pushed by its originator. The jetties have been constructed of mattresses of fascines loaded with stone, and extended to the length originally proposed. By the aid of dredging between the jetties in places, in connection with the scouring effect secured by the jetties, a channel has been obtained more than 22 feet in depth.

The very important question of embanking the Mississippi to protect and reclaim the great alluvial tracts upon each side, as a Government measure, is now being agitated. Thus far the the levee system has been carried on by State Governments and private enterprise, and has been but imperfectly done.

Another great scheme of improvement along the Atlantic seaboard, which was proposed some forty years ago, is now likely to be carried out. This is an internal water communication from New York to Florida. There is a chain of salt water sounds just back of the outer coast, extending through North and South Carolina and Georgia, that can be made available for a continuous water communication, and there is already a communication for small craft from New York to Newbern, North Carolina. A canal is now projected between the Neuse and Cape Fear rivers in North Carolina, as part of the general scheme.

The National Government is at present conducting two important surveys relating to navigation. One, the coast survey embracing the entire seaboard, and the other the survey of the Great Lakes : both of which are being executed with great accuracy. The coast survey is under the immediate control of the Treasury Department, and is chiefly conducted by civilians, while the Lake survey is under the immediate control of the War Department, and is conducted by the United States Engineer Corps.

SUBJECTS EXHIBITED.

43 *and* 44. *Photographs of detail drawings of Iron Snag Boat "McComb," built for use on the Missouri river. Designed by* Major Charles R. Suter, Corps of Engineers, U. S. A.

The Missouri river is a stream of very changeable regimen ; it is constantly washing its banks and changing the course of its channel ; large

quantities of drift wood are brought down by every flood, among them logs and entire trees which caught in the bottom of the river often remain anchored there, the upper end being a little above or below the surface of the water; these are the well known snags so dangerous to navigation. The "McComb" was built to remove them, and is provided with a variety of machinery for pulling them up and cutting them in pieces.

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45. *Photograph of Mouth of Hell Gate Mine, New York Harbor.*

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46. *Photographs of Dredge Boats, one pattern furnished by Vulcan Iron Works, Chicago; one by* W. H. NEWTON, C. E., of Chicago; *one by* R. G. PACKARD, C. E., of Brooklyn.

Description of the Atlantic Dredging Company's Dredge Boat No. 6. Built by R. G. PACKARD, C. E. See Plate LIII.

This dredge, which is equipped with a grapple, opening 15 feet for stone, and a pair of clam-shell buckets containing 10 cubic yards for mud, is capable of dredging in 150 feet of water. The hull is 115 feet long, 37 feet wide, and 12 feet depth of sides.

The cylinders (2) are 26″ diameter and 24″ stroke, horizontal and reversible, working together upon one shaft, driving two drums 3′ in diameter, which drums have friction clutches 12′ in diameter. The pinions and gears of these main drums are 3′ and 12″ in diameter, 4″ pitch and 12″ face. The two main chains are short linked, made of Burden's *best* wrought iron, 1½″ in diameter. In lifting heavy weights, which are sometimes from 50 to 60 tons, both chains are used.

The dredge is moved by six horizontal winch heads, actuated by independent engines, which will pull it, with loaded scow, against a 7 or 8 mile current; each winch head has its own friction clutch and band, so that either or any can be driven while the others hold.

Besides the ordinary anchors, the forward end of the dredge is held by an oak spud, 2′ x 2′, 50′ long, worked by a friction drum driven by the auxiliary engines.

The boiler is 18′ 4″ long, 7′ diameter, and has 2 furnaces 9′ long; 10 flues 7′ long, and 65 four-inch return flues each 16′ long; it will carry 85 lbs. of steam.

When dredging in mud two buckets full per minute are deposited in scow alongside, when the depth is not over 20 feet.

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47. *Photograph of hull of United States Dredge Boat* "*McAlister.*" *Designed by* EDWARD MARSLAND, C. E.

The propeller screw of this boat is used to loosen the material, which is then removed by a current of water produced by a pump.

48. *Detail Drawings showing system of Levee Construction in Louisiana. Contributed by* LOUISIANA BOARD OF STATE ENGINEERS.

These comprise four maps, viz. :

A map of a "cut-off," which is the most active agent in causing the caving of banks, the destruction of levees and the opening of crevasses.

Two maps of a crevasse, one of the immediate scene and the other of the country devastated. Crevasses chiefly occur on the concave sides of bends from the caving of banks and of the levees located thereon. Accretions form on the opposite point.

A map with sections and profile of a levee built to close a crevasse.

The "cut-off" selected as a type is at Davis Bend, about four hundred and sixty miles above the head of the passes of the river and three hundred and fifty-four miles above the City of New Orleans. Here the concave bends above and below the point caved in, until, in 1867, the neck or isthmus was broken through, and twenty miles eliminated from the length of the river. The fall of these twenty miles was three-tenths of a foot per mile, or five feet for the entire distance, which was concentrated into one-half mile by the "cut-off." The river immediately began to restore its length and regimen by cutting into the concave banks of all bends above and below. This result was distributed with an energy diminishing, but still sufficient to necessitate the construction of new levees, at each bend for seventy-five miles above and one hundred and twenty-five miles below the "cut-off."

The type of crevasses selected is at Bonnet Carré, one hundred and forty miles above the head of the passes and thirty-four miles above the City of New Orleans. In this bend five crevasses have occurred in the last twenty-five years. The present break has been running since 1874. It overflows upwards of one hundred square miles of land, capable of producing a crop of 2 000 pounds of sugar per acre, and a large swamp tract. Lake Pontchartrain, in the rear of the crevasse, valuable for navigation, sanitary and drainage purposes, is much impaired by deposit brought in the water from the crevasses.

The closing of crevasses is exemplified by a map of the "Bass Levee," built in 1877, about five hundred and fifty miles above the head of the passes. The crevasse closed thereby had been running since 1873, with results more disastrous than those at Bonnet Carré. The new levee is five and a half miles long, height varying from 6.5 to 21.3; average 10.8 feet. Slopes 3 to 1. Contents 487 991 cubic yards. Cost \$120,373.$\frac{67}{100}$, at 24 cents per cubic yard.

Two Models of the South Pass of the Mississippi River, showing Jetties constructed by JAMES B. EADS, C. E.

The first model represents the mouth of the South Pass as it was in May, 1875. It shows the eastern and western land ends, and the gradual rise of the bottom towards the crest of the bar. The upheavals

of the Gulf bottom beyond the bar-crests are the mud lumps, characteristic in the formation of the delta of the Mississippi River. The soundings which have been used in the preparation of this model were made by the officers of the United States Coast Survey, as shown by their chart, in May, 1875. The depth which then could be carried over the bar into the Gulf of Mexico was nine feet at average flood tide.

The second model represents the mouth of the South Pass as it was in April, 1878, after being improved for navigation by the application of jetties. The location of the jetties is indicated by light colored walls, and the height given to them corresponds with the elevation the stone-covering will have after the jetties are finished.

The jetties are constructed of willow mattresses, which are sunk by stone. The small dams projecting into the channel are wing dams of temporary character and importance; they are designed to hasten the scour in the centre. The soundings which have been used in the preparation of this model were made in April, 1878.

By comparing the two models with each other, the following facts will appear:

1. A channel has been excavated throughout the entire length of the old bar large enough to permit the passage of ocean vessels of 23½ feet draft from New Orleans to the Gulf.

2. No new formation of the bar beyond the sea ends of the jetties has taken place. The models show the summits of the old lumps to have been worn away by the power of the deep fresh water current which emerges from the mouth of the jetties.

3. The bottom at the sea sides of the jetty walls has filled up nearly to the height of the jetties, thus giving a complete protection to the jetties from storms and waves.

4. Considerable changes in the outlines of the shore line have taken place, due to the confinement of the water in one narrow channel.

Drawings of Inclined Plane and Caisson connecting the Chesapeake and Ohio Canal with the Potomac River at Georgetown, D. C. WILLIAM R. HUTTON, Engineer. (See Plate LIV.)

The work consists of a caisson, in which the barge floats, traveling upon the rails of an inclined plane from the head bay at the Canal, to descend into the water of the river. It is balanced by two counterweights, and the motive power is supplied by a turbine wheel, worked by water from the canal, which turns the grooved pulleys around which the cables pass which connect the caisson with the counterweights. The caisson is of plate iron and rolled beams, the counterweights are timber frames filled with masonry.

Each cable is attached to the head wall, passes through a sheave on the counterweight, makes two and a half turns around the pair of grooved

wheels, and is attached to the caisson ; by this arrangement the travel of the counterweights is but half that of the caisson.

The grade of the main track is one in twelve—that of the counter-weight tracks, one in ten, and at the upper end, one in twenty. The grade was made lighter at the upper part to relieve the tension of the cables on the side of the counterweights when the caisson is immersed. On account of the variation of the level of the river surface, the diminished weight of the immersed caisson cannot be entirely compensated by this arrangement.

The descending boats are always loaded. Those ascending are empty.

The caisson descends full of water—it ascends full only to the bottom of valve openings in the rear gate.

The counterweights are a mean weight between the caisson full, descending, and the same ascending partly full. The descending side is therefore always the heavier, but the difference is not equal to the friction of the system.

The caisson is furnished with pawls dropping into the teeth of a ratchet rail on the track, and with brake shoes. Both are raised by hand and both may be tripped from the foot board of the caisson.

The maximum lift is 39.36 feet at extreme low tide. The minimum 36.75 feet at extreme high tide, or with a slight flood.

Length of caisson 108.25 feet, width in the clear 14.75 feet, draft of barges 5 feet. Load carried by barges 115 to 125 tons. Weight of caisson full, 360 tons, weight of each counterweight, 300 tons.

Each counterweight is furnished with pawls, which are raised and lowered by hand ; and with brake shoes which act automatically in case the main cable should break.

The caisson is held close to the head wall, while the gates are opened, by a hydraulic press worked from an accumulator. The press acts upon a wheel upon the main shaft, which when in gear turns the shaft, and through it the grooved wheels, to hold the caisson to the wall.

The rails are secured to wooden stringers, bolted to masonry walls, which are founded on the rock. The first rails were made of cast iron, because of the difficulty in getting ordinary rolled rails with a sufficiently broad flat head for the bearing of the wheel. They have been in great part replaced with steel rails, with a flat top.

The river wall was built in water 19½ to 23 feet deep by the system Beaudemoulin.

The work was constructed by the Potomac Lock and Dock Company, H. H. Dodge, President, and is leased and operated by the Chesapeake and Ohio Canal Company, A. P. Gorman, President.

GAS ENGINEERING.

To represent gas engineering, the Society was able to exhibit drawings and photographs of works and apparatus as employed in this country, which in some respects are novelties. The progress made in this branch of engineering is perhaps more marked than that of any other department. In fact, the beginning of the century knew no such business; fifty years ago New York city had no gas, and forty years since, all the gas supplied to the people of Boston was made in one iron retort.

The amount of capital now invested in this business in New York city and Brooklyn is represented by about thirty millions of dollars, and the number of works, great and small, throughout the country is about one thousand. The principal progress that has been made since the earlier days of gas lighting consists in the various scientific and mechanical means introduced for the proper treatment of the products derived from the destructive distillation of coal, so that while those portions that constitute the light-giving power of the gases evolved are carefully separated in a state of "purity" or freedom from the more deleterious elements, the other portions are still preserved, and handled in such a way as to be no longer "waste products," but sources of revenue in the production of articles of great value and usefulness in the arts. And while this country cannot claim so great a degree of perfection in this latter respect, viz., in the handling of residual products, as has been attained

abroad, the reason for this is to be found in the fact that the newness and fertility of our country does not afford the same market demand for these products.

The exhibits under this head consist of—

A detailed drawing of a multitubular condenser.

Photographs of a modification of the Livesey scrubber, with an automatic water distributing apparatus.

A complete drawing of the works of the New York Gas Light Company.

Photographs of the Nassau Works of Brooklyn, &c., &c., &c.

The multitubular condenser is an apparatus for condensing the tar from the gas. It consists of a cast iron box, or series of boxes, with two horizontal diaphragms or partitions—one near the top, the other near the bottom; the upper and lower spaces thus formed are connected by cast iron pipes, usually about four inches in diameter, placed as closely together as possible. The middle space of the box is filled with water, which consequently surrounds the pipes above mentioned.

A series of boxes thus arranged are placed side by side, the gas is admitted into the lower space and passes up through the pipes to the upper space, from there it goes to the top space of the next box, down the pipes to the bottom space, thence into the next box, up the pipes, and so on, thus traveling up one set and down the other until the temperature of the gas is reduced sufficiently low by the water surrounding the pipes to cause the tar, &c., to be deposited in the lower space, from which the tar is run off into cisterns constructed for the purpose. The water surrounding the pipes is admitted from the end of the series of boxes opposite to that at which the gas enters, so that the water surrounding the pipes through which the gas first passes is the warmest (the heat having been acquired by the flow of gas), and that at the end where the gas leaves the condenser is the coolest. In this way the cooling of the gas goes on gradually, and is not too sudden in its change of temperature at any point, and the rapidity of cooling is easily controlled by regulating the amount of fresh water admitted to the condenser.

This form of condenser is largely used in this country, but is almost unknown in Europe, where, as a general thing, the temperature of the air is relied upon to cool the gas, which is passed through pipes out of doors for the purpose. The great advantage of the multitubular method

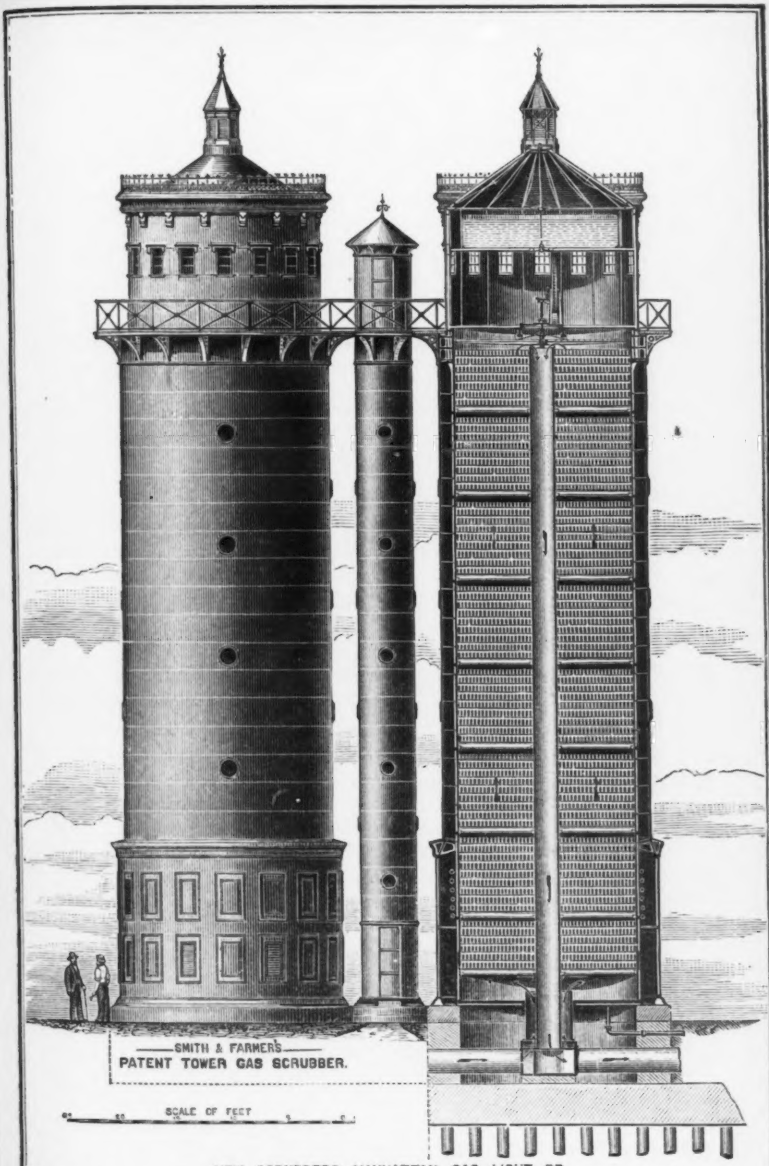
is the almost perfect control that it gives the manager over the rate of cooling. In submitting the drawings of this apparatus, the Society was enabled to present a novelty to the gas engineers of Europe.

Of the scrubbers of which photographs were submitted, and of which a drawing is shown on the opposite page (Plate LV.), the principal novelty consisted in the method of distributing the water. The object of the scrubber being to remove the ammonia from the gas by the use of water, by means of the distributer on the top the same water that is used to wash the gas is made to distribute itself by passing from a tank overhead, to which it had been previously pumped, over an overshot water wheel, which, by suitable gearing, turns two arms within the top of the scrubber, into which the water is conducted by a pipe leading from a trough under the water wheel. These arms are in the form of troughs, with notches cut in the edges, so that as the arms revolve horizontally the water drops on to the wooden slats with which the scrubber is filled. These slats being put in edgewise and kept a small distance apart, a very large area of wetted surface is presented to the gas as it passes through. The ammonia is taken up by the water, which passes off from the bottom as "ammoniacal liquor," and is collected in cisterns built for the purpose. The gas enters the scrubber at the bottom, and passing up to the top, is taken out by a central outlet pipe, which extends to the top. The gas on entering comes first in contact with the strongest liquor, and leaves through a spray of clean water. The strength of the liquor obtained from these scrubbers is from 16 to 20 ounces Twaddle. The quantity of water used is about one gallon to 1 000 feet of gas.

The photograph of the Providence Holder House shows one of the largest domes in tbe world.

The photographs of the works of the Nassau Company represent one of the most complete of our modern works.

The colored drawing of the plant of the New York Gas Light Company, aside from its accuracy of detail, shows the plan of the largest holders in the United States at the present day.



ERECTED 1876 — NEW SCRUBBERS. MANHATTAN GAS-LIGHT CO. — C.V.SMITH. ENGINEER

C.WRIGHT

RAILROAD FORMS.

SUBJECTS EXHIBITED.

Album contributed by the Lake Shore & Michigan Railway Company.

This album is made up from the printed documents and blank forms used by that company in its several operating departments; beginning with a map showing the relation of its lines to the railways of the Northern and Western States, and another, showing, upon a larger scale, the country which they specially serve, as also the roads which contribute to, or compete for its traffic.

These are followed by an account of the growth of the present company through a consolidation of numerous smaller corporations, with a table of the earnings of all the corporations from their beginning. Othe tables give information of the financial condition of the company, and a complete account of its operations during the year 1877, with their results.

This is followed by the regulations printed for the employés of the company in the departments of the General Superintendent and Chief Engineer; comprising the general rules for the government of all, and the special rules for conductors, brakemen, newsboys, engineers, firemen, station agents and ticket agents; for the use of air brakes; for the care of injured persons; for telegraphers and for the baggage department; also, information for the public of the conditions upon which baggage will be carried.

The remainder of the Album is filled with the printed notices and blanks of each of the departments, arranged in groups according to the department by which they are used.

In this way, it was hoped to present a general view of the modes of advertising adopted by the passenger department; of the system of reports required by the General Superintendent, Chief Engineer, Auditor and other officers, from their subordinates; of the methods of billing freight over the railway from one station to another; from this railway to any other railway and to foreign parts, together with the reports of the tonnage and charges, which are made to the General Freight Agent. The blanks

used for reporting the mileage of its own cars upon its road, and the sheets upon which the miles run by each car are recorded; also, the method of reporting daily to other lines the miles run by their cars upon this road, are grouped under the head of Car Recorder's Department.

The various forms of passengers tickets used in through, way, excursion, emigrant, special and foreign business, are illustrated by samples of each kind; as, also, the manner in which sales of each are reported to the General Ticket Agent and Auditor.

In many, or perhaps in all their details, the forms and methods of each Department differ from those used by other railways of the United States; yet, by nearly all those railways the same general manner of carrying on their business is employed, so that this Album may be taken as a brief exposition of the way in which railway transportation is conducted in the States of the Union. As a rule, passengers and freights, traversing the main routes, are transported without change of cars, and are billed and ticketed through from the start to destination, so as to avoid delays.

It is the custom among the railways to accept the bills of lading and tickets issued by one road over any of the others. The manner in which contracts. shipments of freight, sales of tickets and divisions of receipts are reported, by one road to each of the others interested, is illustrated by the forms given in the Album.

The settlements of balance is effected between the roads acting as individuals (not through a clearing house), except in the case of what are known as Line Freights.

The Freight Lines of the United States are of two kinds, private and co-operative; and were established to facilitate the forwarding of goods over long distances, by acting as an intermediary for the shipper and for the many railway lines, over which the goods might have to pass to their destination.

The General Agencies of these lines, act as clearing houses between the several railway companies which they represent.

The co-operative lines are owned and operated by the railway companies over which they pass; the cars being furnished by each railway, its proportion of the general expenses being in the ratio of its length, to that of the whole distance traversed.

The private lines furnish cars and agencies upon a contract with the railway companies; many of the companies owning a part of the stock of the private lines.

Album contributed by the Providence & Stonington Steamship Company.

This album, like the preceding, contains samples of the company's business blanks, advertising posters, tickets, plans of the staterooms on the boats, and a full set of baggage checks. It also has a history of steamboat navigation on Long Island Sound from 1792 to the present time.

GENERAL DESCRIPTION OF EXHIBIT.

The drawings and photographs are grouped in departments, and mounted on a structure erected for the purpose, where, together with the models and specimens, which are also conspicuously displayed, they may readily be seen and examined by all visitors to the Exposition. The tracings, albums, specifications, blank contracts, lithographs and other miscellaneous matter, not designed for general exhibition, are accessible to engineers and others who may desire to make special investigations.

The structure on which the drawings, photographs and models are exhibited was built by Messrs. Mead & Taft, of Cornwall-on-the-Hudson. All parts, except the interior frame, which is concealed by the drawings, are of American hard woods. It is an excellent example of first-class machine-made carpenter work, and in itself forms a good collection of native finishing woods.

This structure is 16 feet wide by 21 feet long. Its exterior surface furnishes six alcoves, each appropriated to a different department, while additional wall surface is provided in the interior, and a broad staircase leads to a platform above.

Four of the six alcoves are at the corners of the structure, and each of them affords three vertical wall spaces 3 feet wide by 5 feet high, two inclined spaces 3 feet square, and one smaller triangular space; the other two are in the middle of the long sides, and twice the size of the others. A copy of the only photograph of the Exhibit received from Paris is given herewith.

The six alcoves are appropriated to the following general departments: Foundations and Masonry, Bridge Superstructures, Hydraulic

Machinery, Inland Marine, Rolling Stock, River and Harbor Improvements.

The Society is greatly indebted to the Engineers Club of St. Louis, which undertook the task of preparing and collecting the drawings and photographs of the works which are represented from that section of the country. The promptness and care which these gentlemen showed in this connection did much to enable the Committee to make a satisfactory exhibit.

Besides the individual exhibitors hitherto mentioned, the Society is indebted to Mr. Frank Thomson, General Manager of the Pennsylvania Railroad Company for two very large photographs of locomotive and fully equipped passenger and express train on that road; to Mr. C. Vandervoort Smith, of the Manhattan Gas Company, Mr. T. K. Lees, of the New York Gas Company, Mr. J. H. Armington, of the Brooklyn Gas Company, Mr. F. S. Benson, of the Nassau Gas Company, and Mr. G. W. Dresser, of the *Gas Light Journal*, who contributed the exhibits referred to in the article on Gas Engineering; to Mr. C. C. Martin, for the photographs of the towers of the East River Bridge, in process of construction; to Mr. Moses Lane, for photographs of the Milwaukee pumping engine, and Milwaukee ship yards; to Mr. T. Guilford Smith, for harbor and lake photographs at Buffalo; to Mr. P. H. Dudley, for an automatic dynograph record; to Mr. S. H. Shreve, for a number of copies of his Treatise on the Strength of Bridges and Roofs; to Mr. T. S. Sedgwick, for his Treatise on Inclined Planes for Canals; to *The Railroad Gazette*, which has sent bound volumes of its paper and copies of its publications; to Mr. John Reid, of Paterson, N. J., for an album of photographs of bridges and other engineering works; to Mr. J. Mullen, of Lexington, Ky., for photographs of Ohio River Bridge; and to many other parties who have contributed tracings, photographs, photo-lithographs, chromos, engravings and water color sketches of bridges, roofs, buildings, rolling stock, machinery, steamboats, dredges, coal mines, and works in progress, as well as specifications for various engineering matters, reports of cities and boards of public works, and pamphlets explanatory of exhibits.

PLATE I
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII N° 1

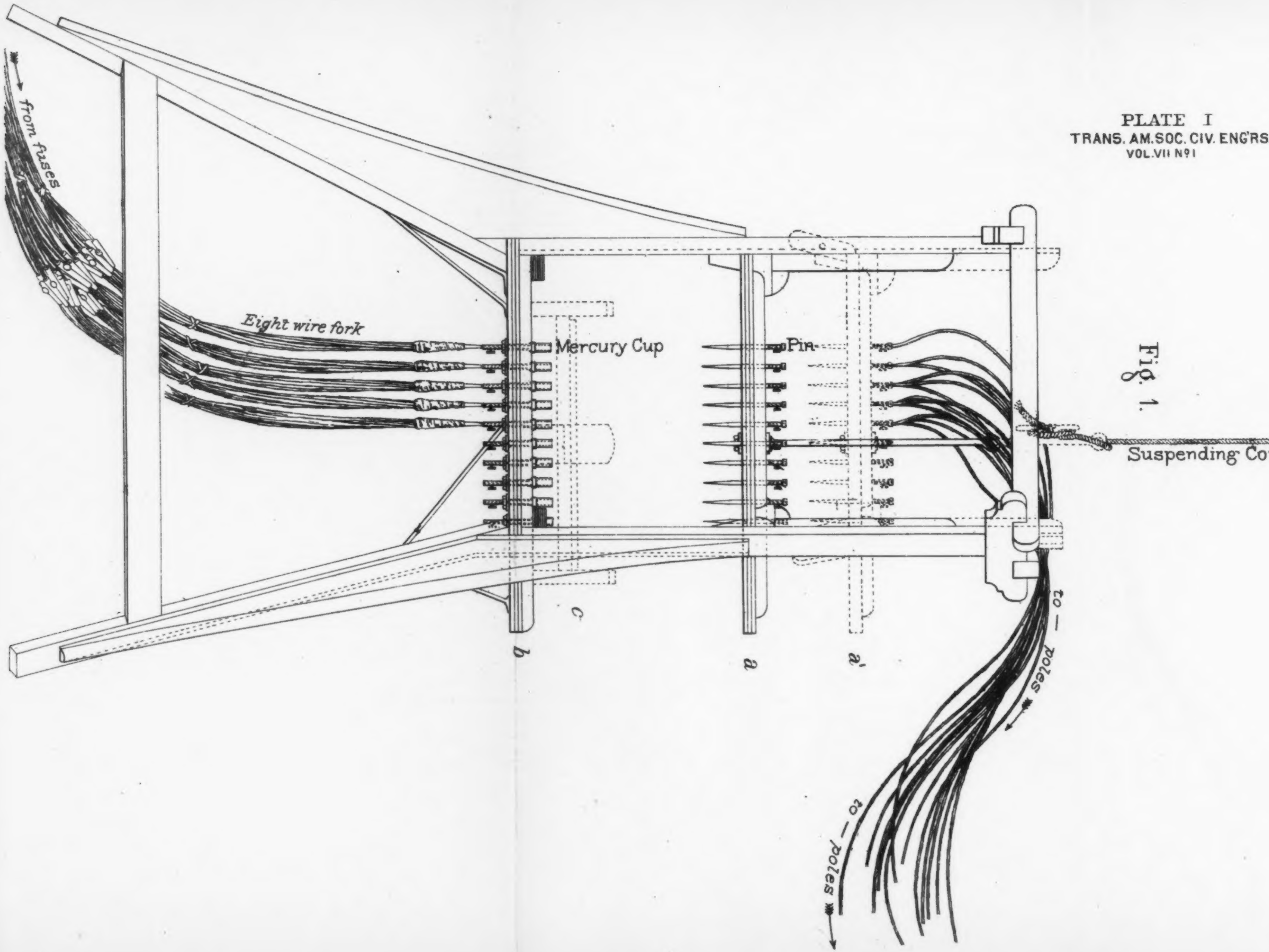


Fig. 1.

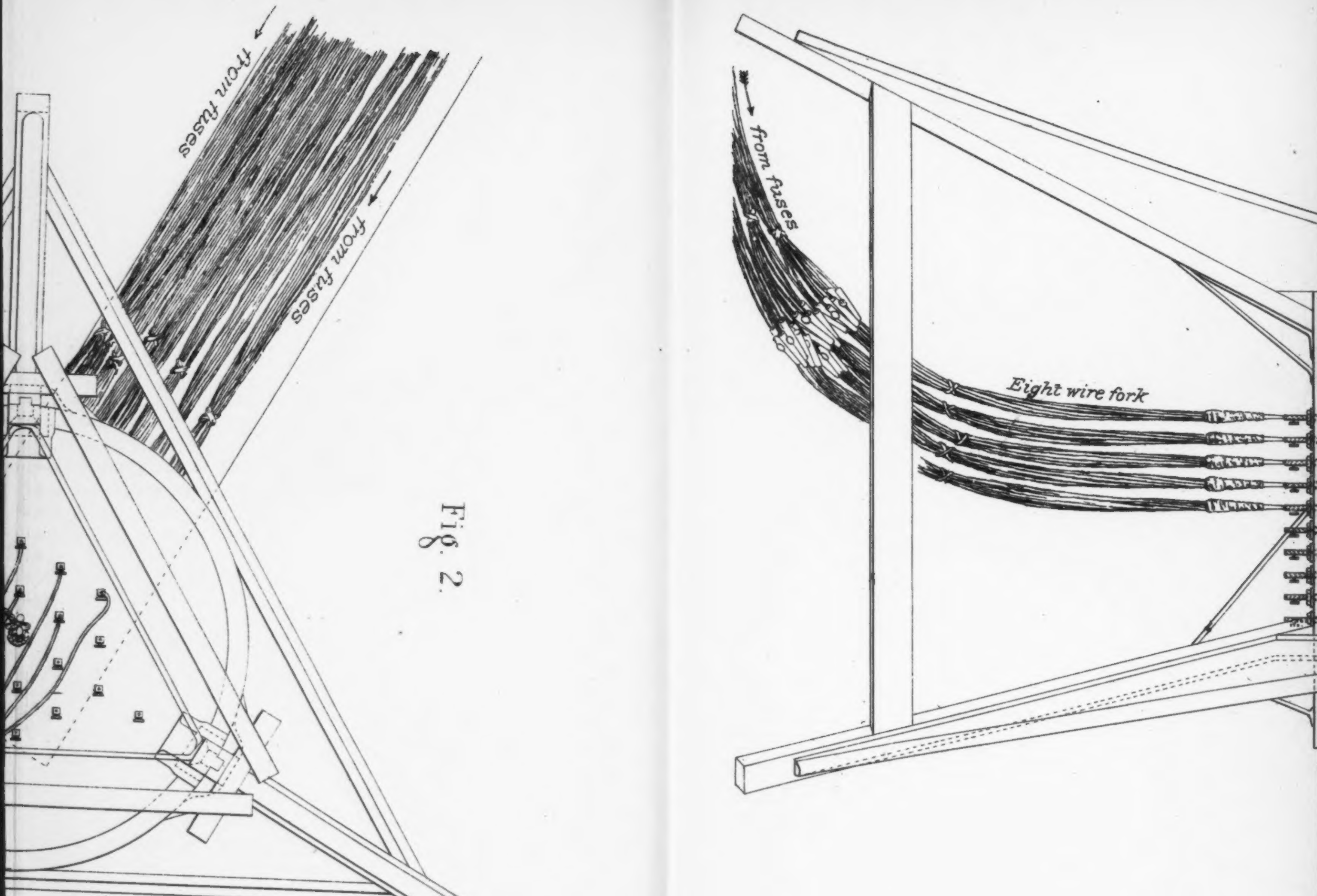


Fig. 2.

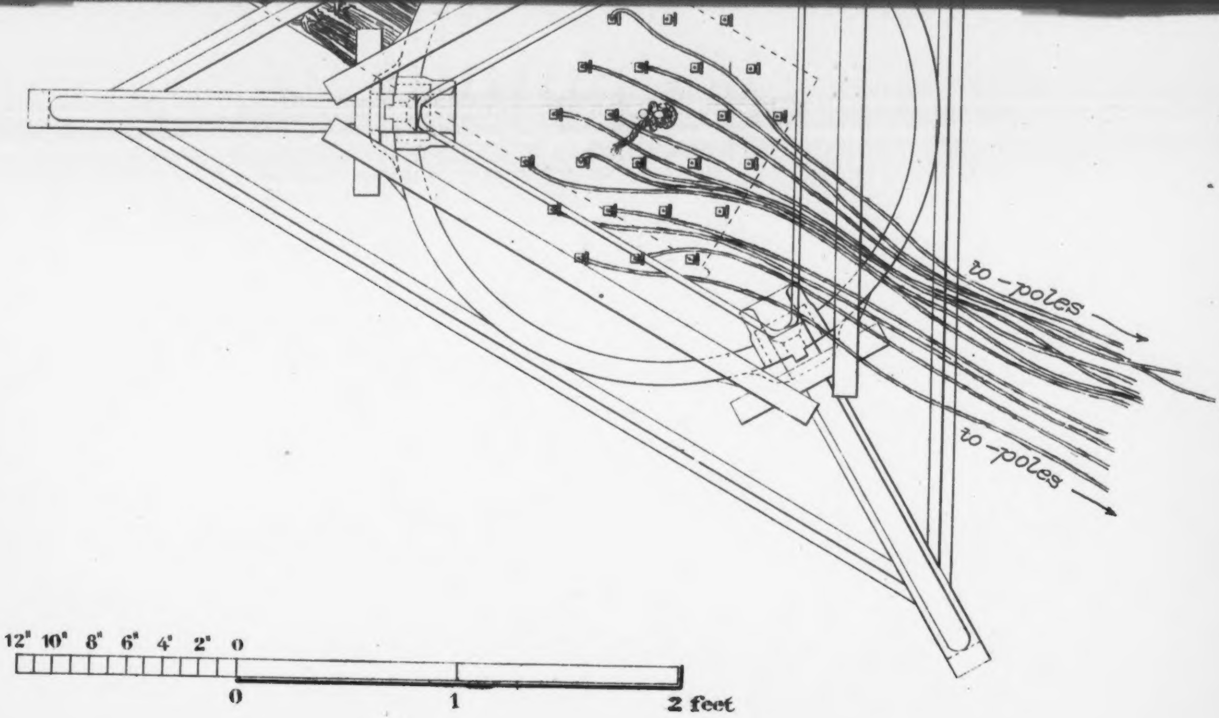

to-poles
to-poles
12" 10" 8" 6" 4" 2" 0
0 1 2 feet

PLATE II
TRANS. AM. SOC. CIV. ENG'RS
VOL. VII Nº1

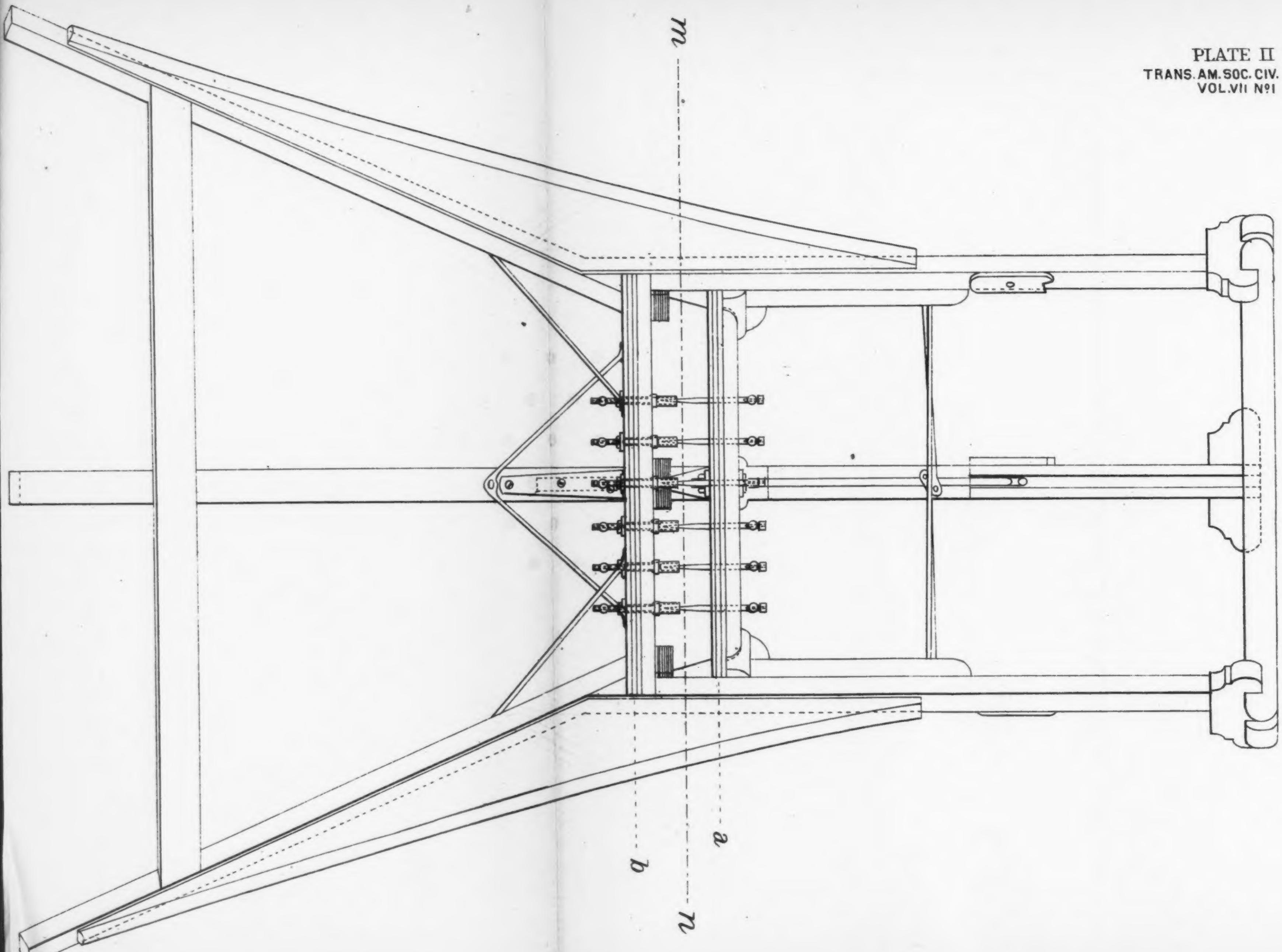


Fig. 3.

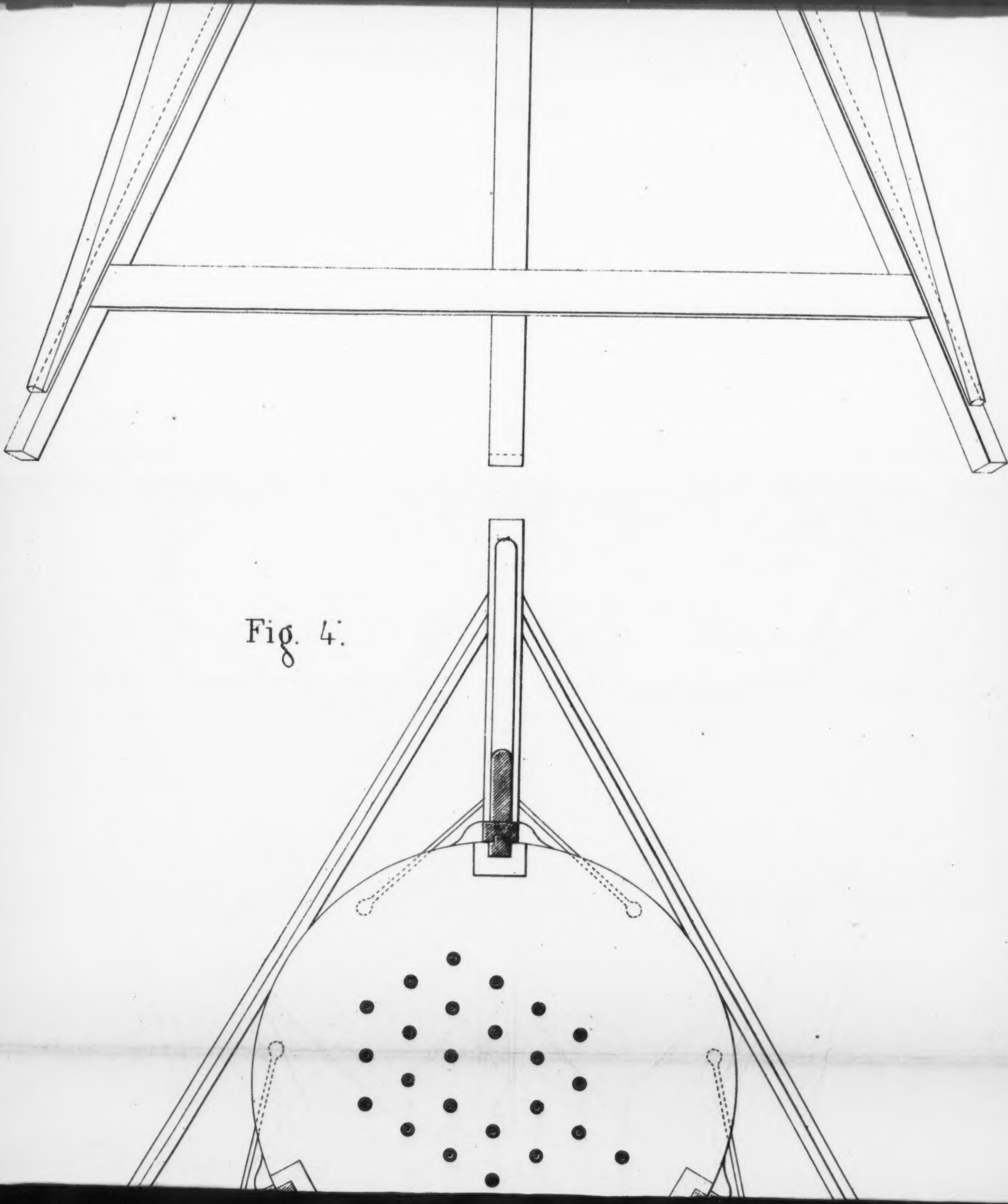


Fig. 4.

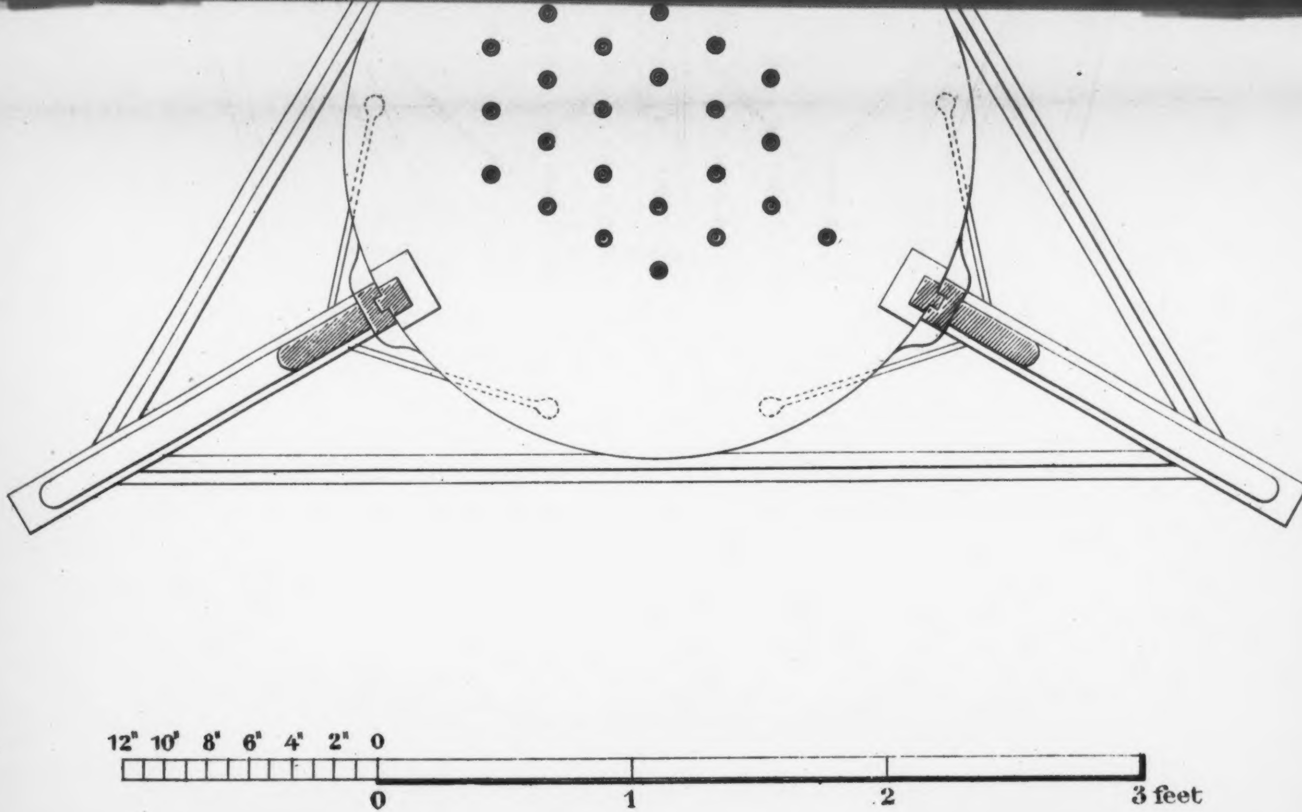

12" 10" 8" 6" 4" 2" 0
0 1 2 3 feet

PLATE III
TRANS AM. SOC. CIV. ENG'RS.
VOL. VII No I

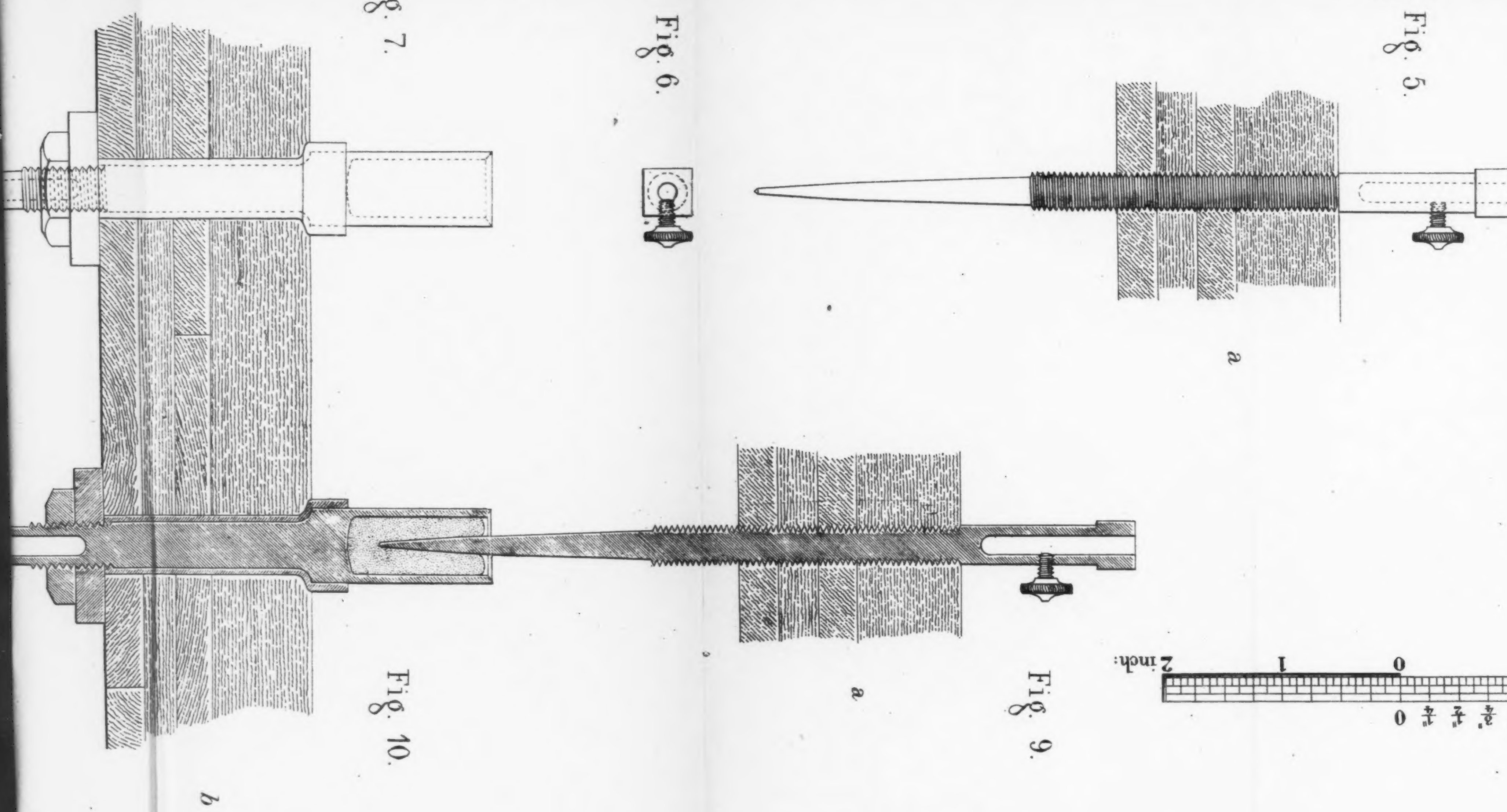


Fig. 5.

Fig. 6.

Fig. 7.

Fig. 9.

Fig. 10.

Fig. 6.

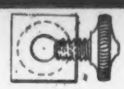


Fig. 7.

Fig. 10.

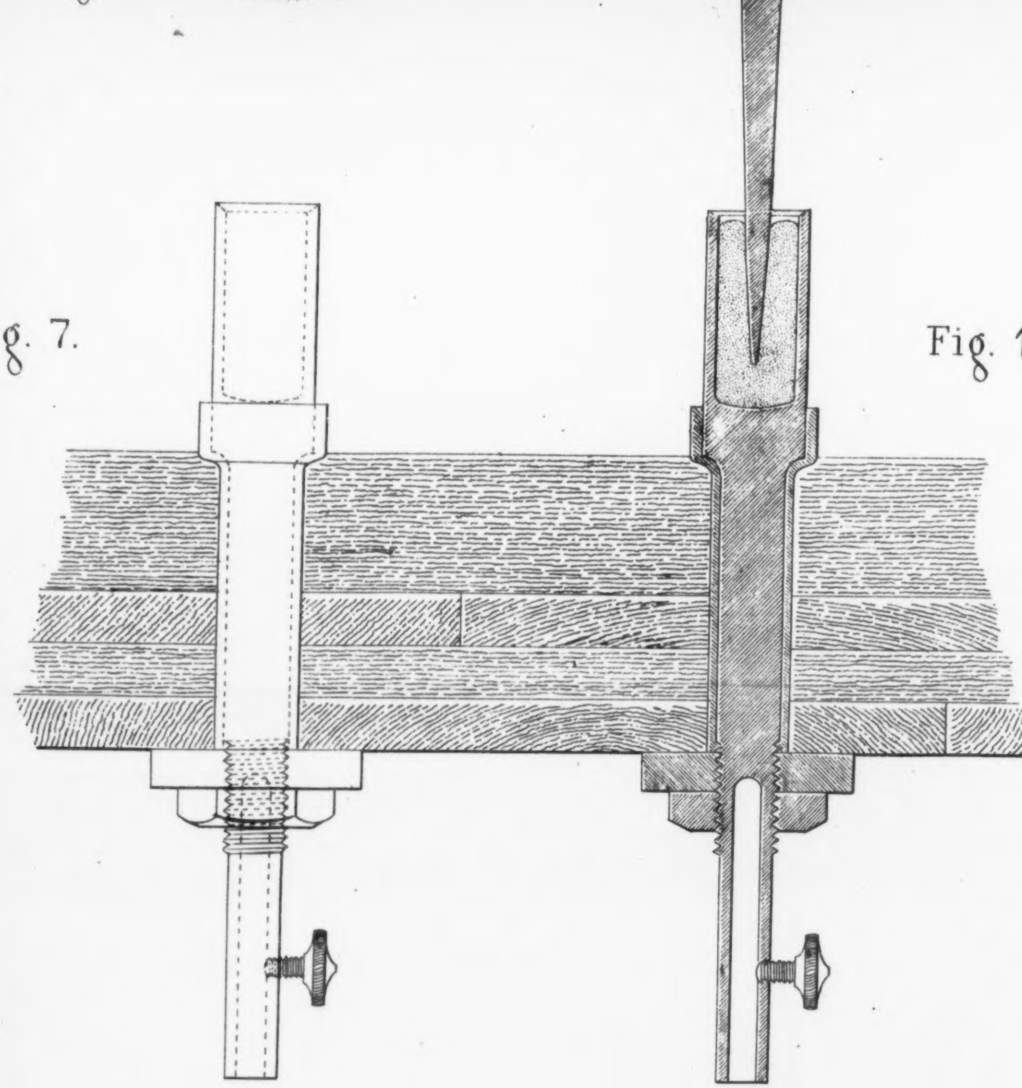
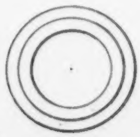


Fig. 8.



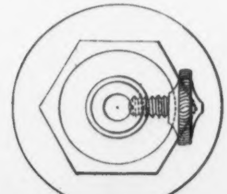


Fig. 11.

Fig. 12.

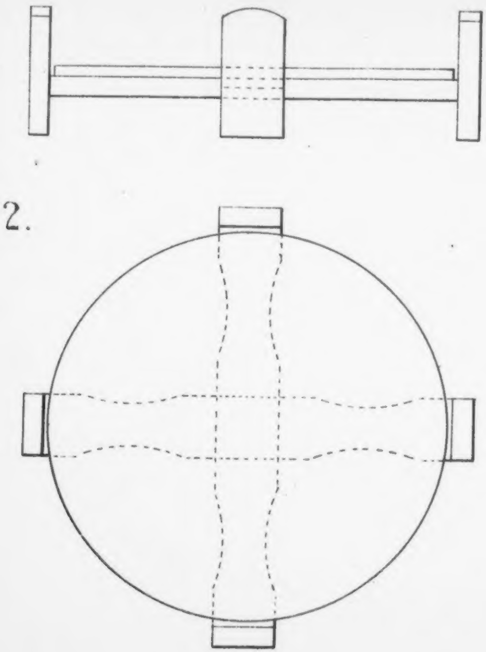


Fig. 13.

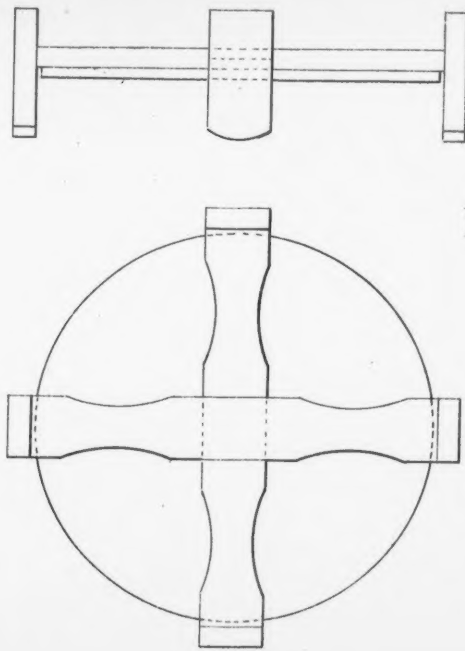


Fig. 1

Outside view of guttapercha covered fuse.

(Full size.)

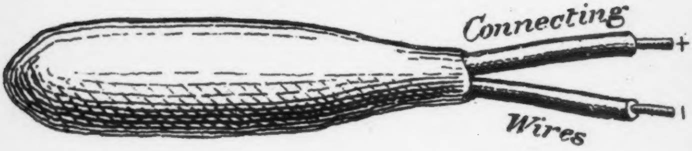


Fig. 2

Forming the copper priming case.

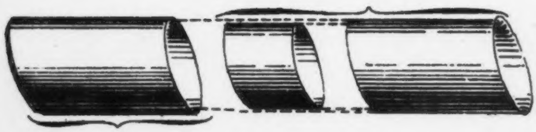
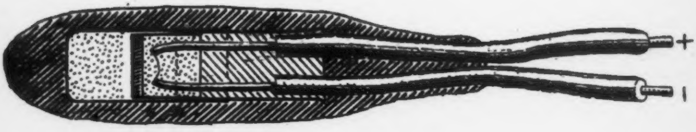


Fig. 3



Sectional view of guttapercha covered fuse.

(Full size.)

PLATE V
TRANS. AM. SOC. CIV. ENG'RS
VOL. VII No. 1

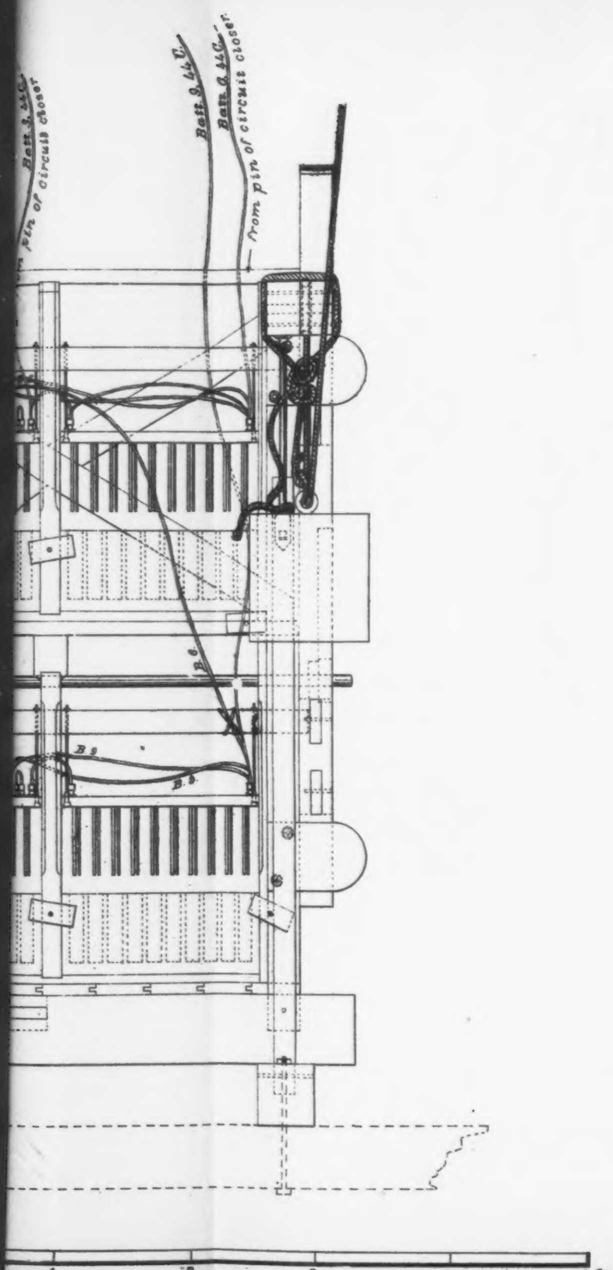
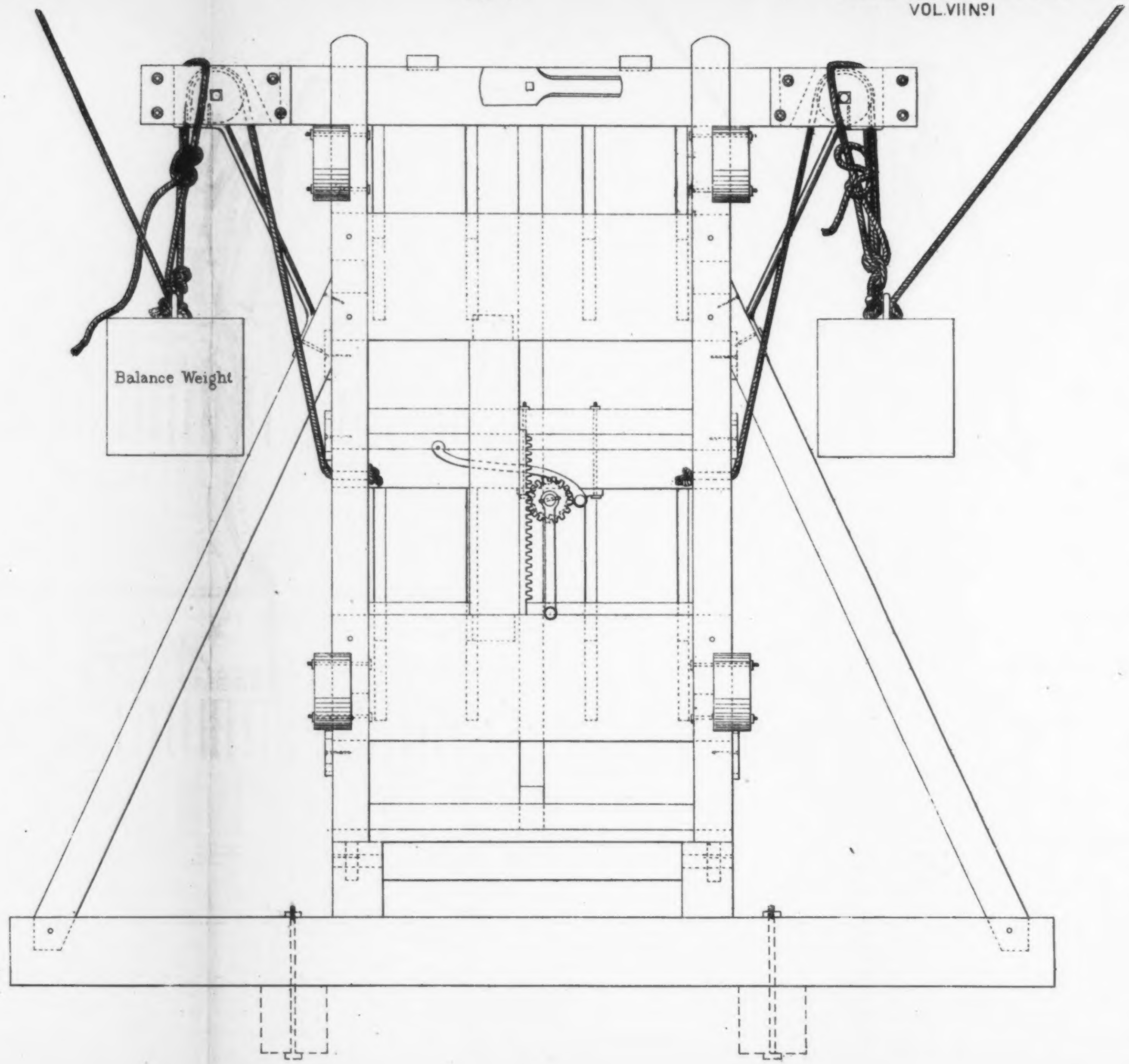
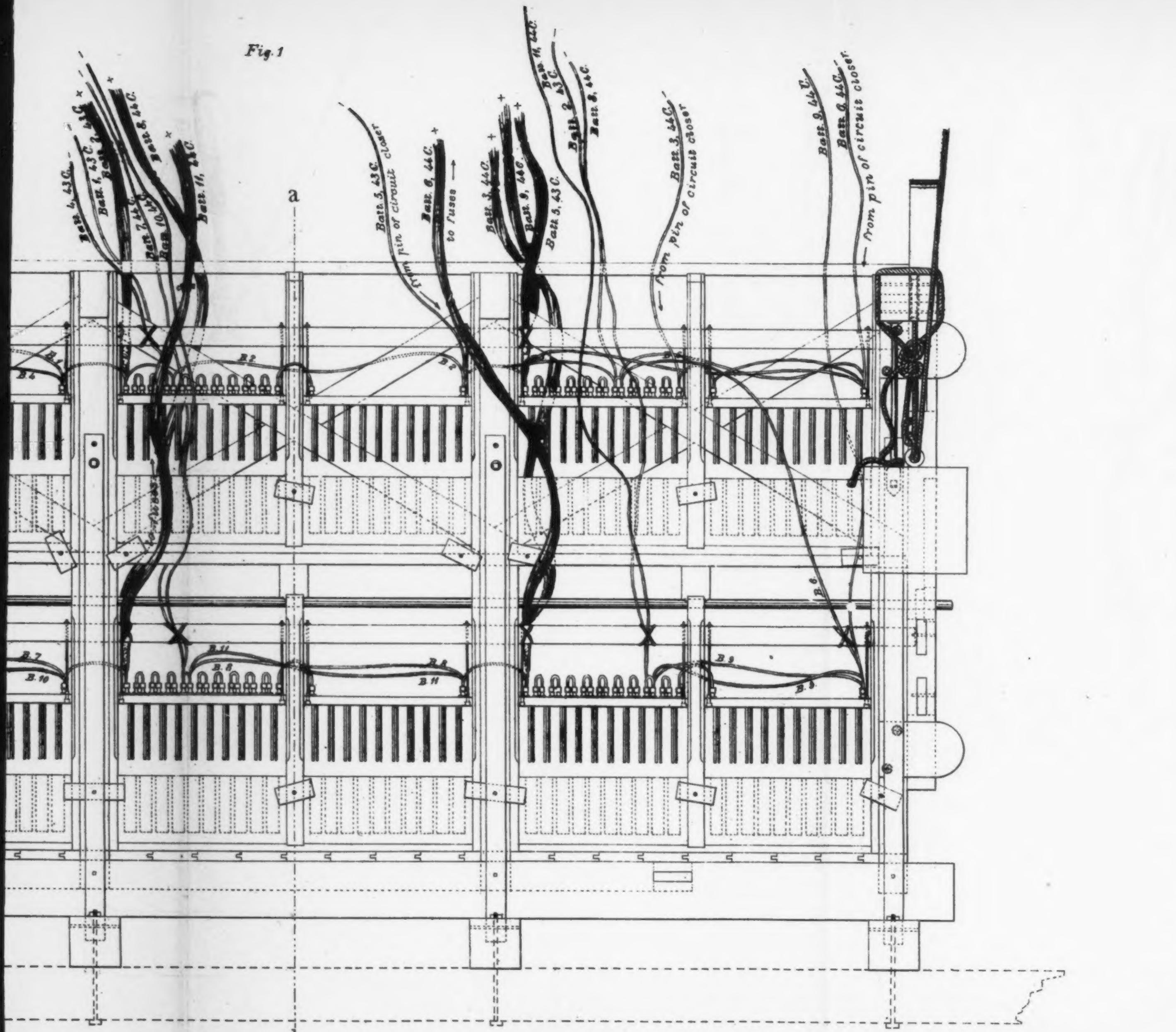


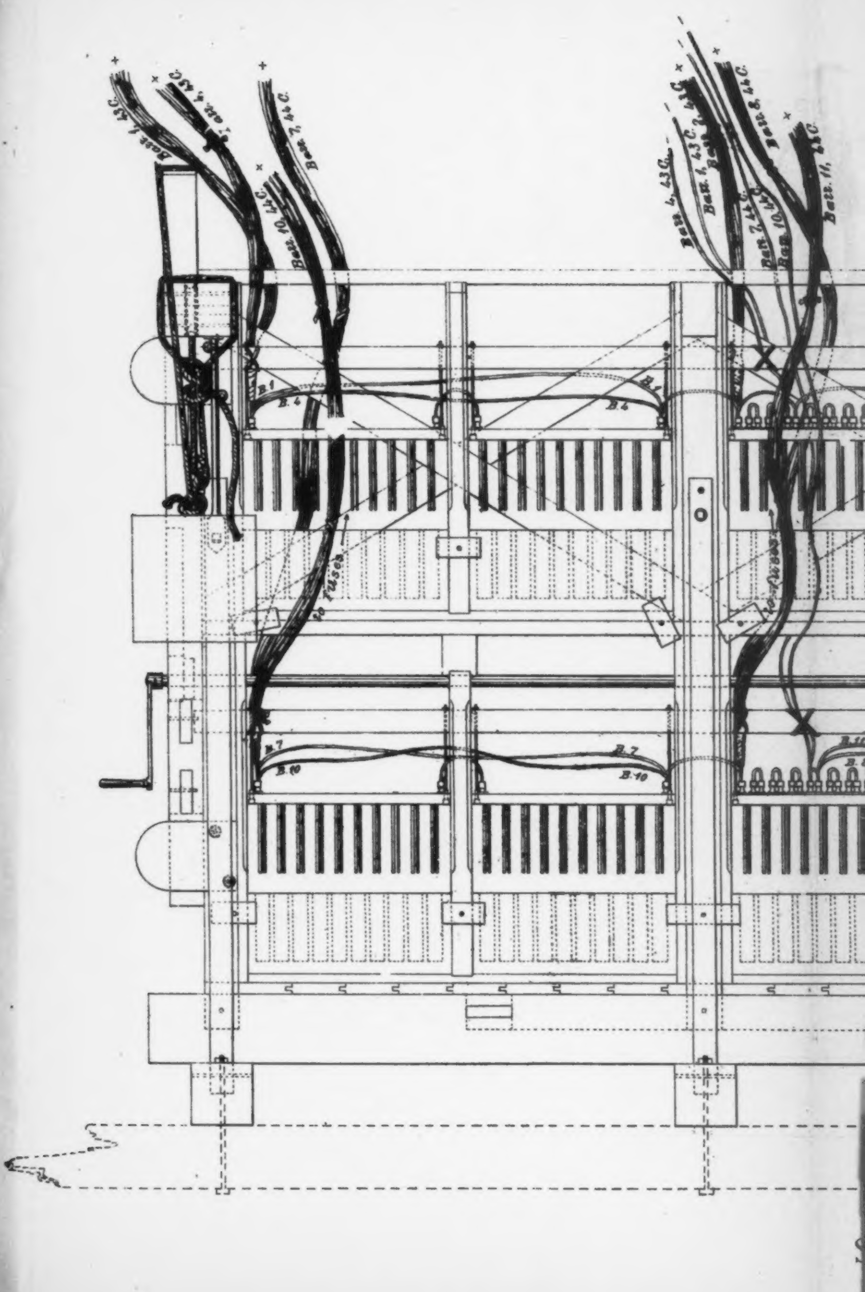
Fig. 4



End Elevation



Side Elevation



Batt. 1, 43C.
Batt. 7, 44C.
Batt. 10, 44C.
B.1
B.4
to fuses
B.7
B.10
Batt. 4, 43C.
Batt. 1, 43C.
Batt. 7, 44C.
Batt. 8, 44C.
Batt. 11, 44C.
to fuses

PLATE VI
TRANS. AM. SOC. CIV. ENG'RS
VOL. VII No. 1

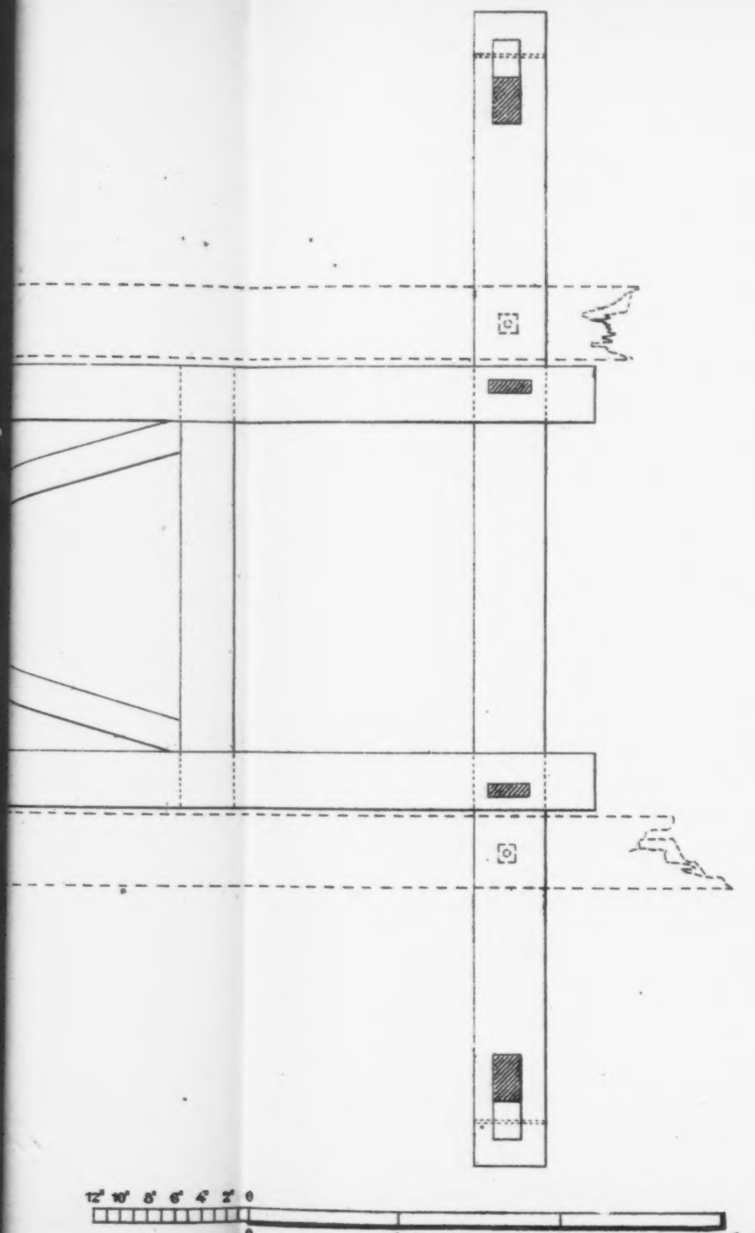
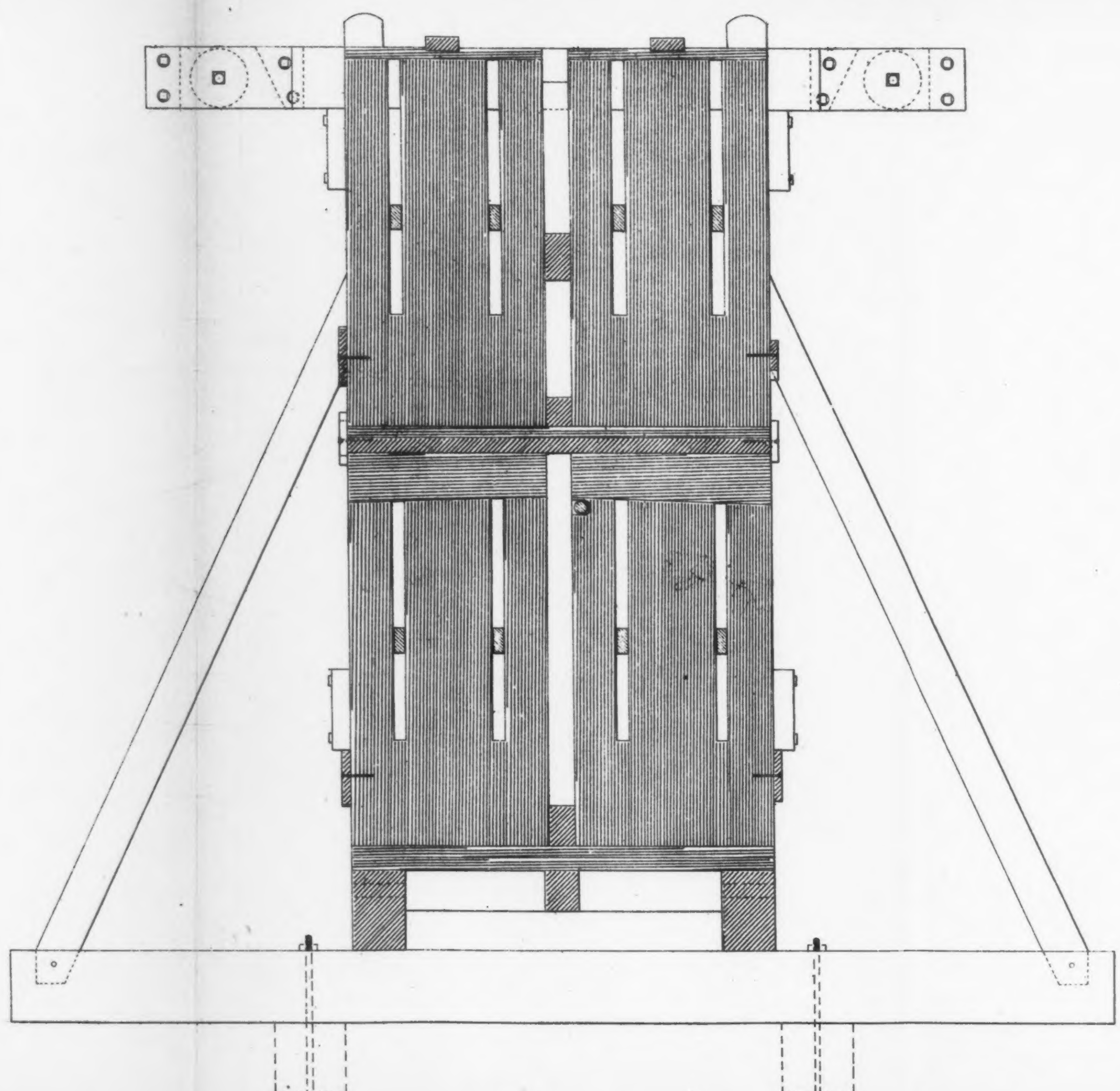
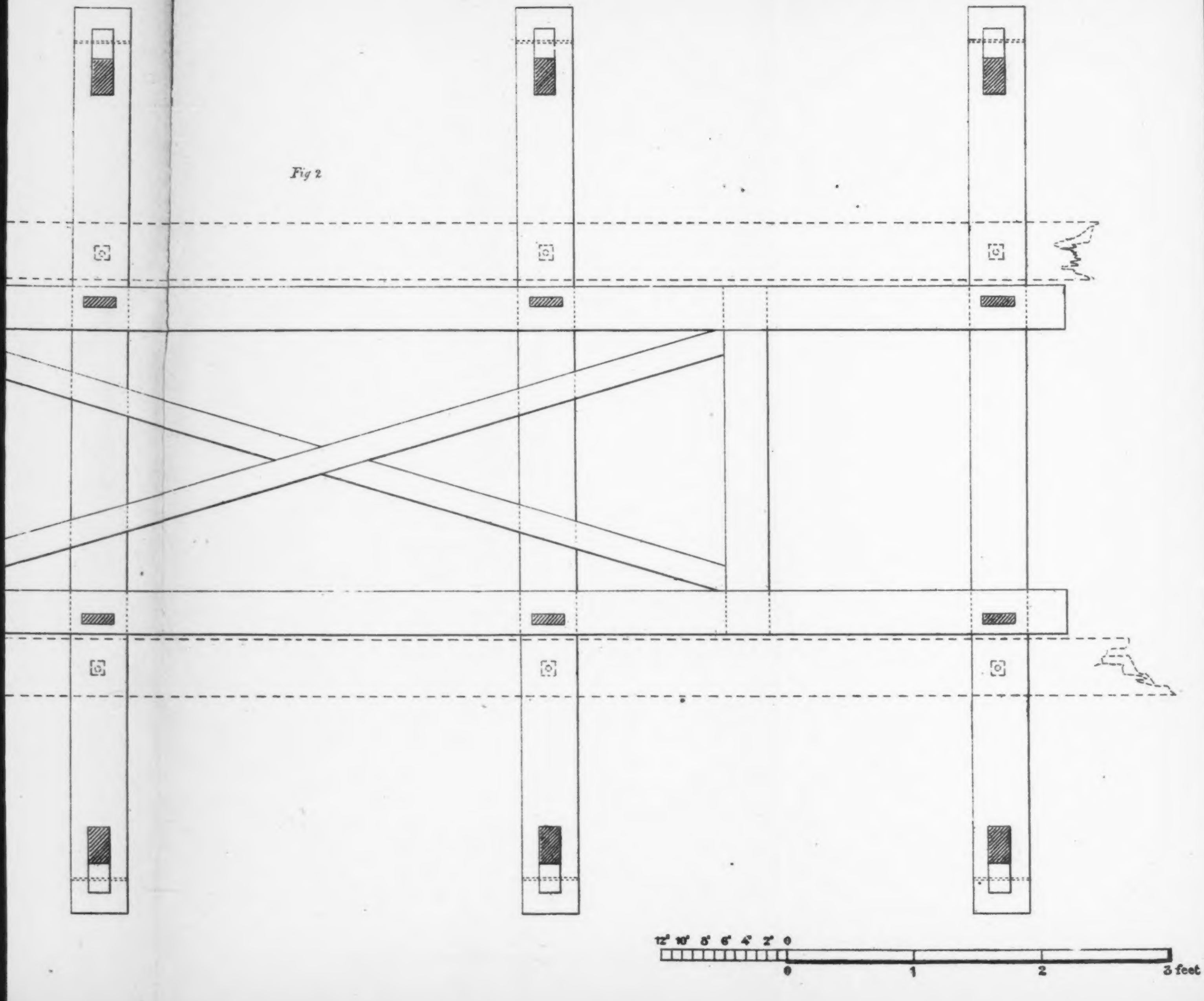


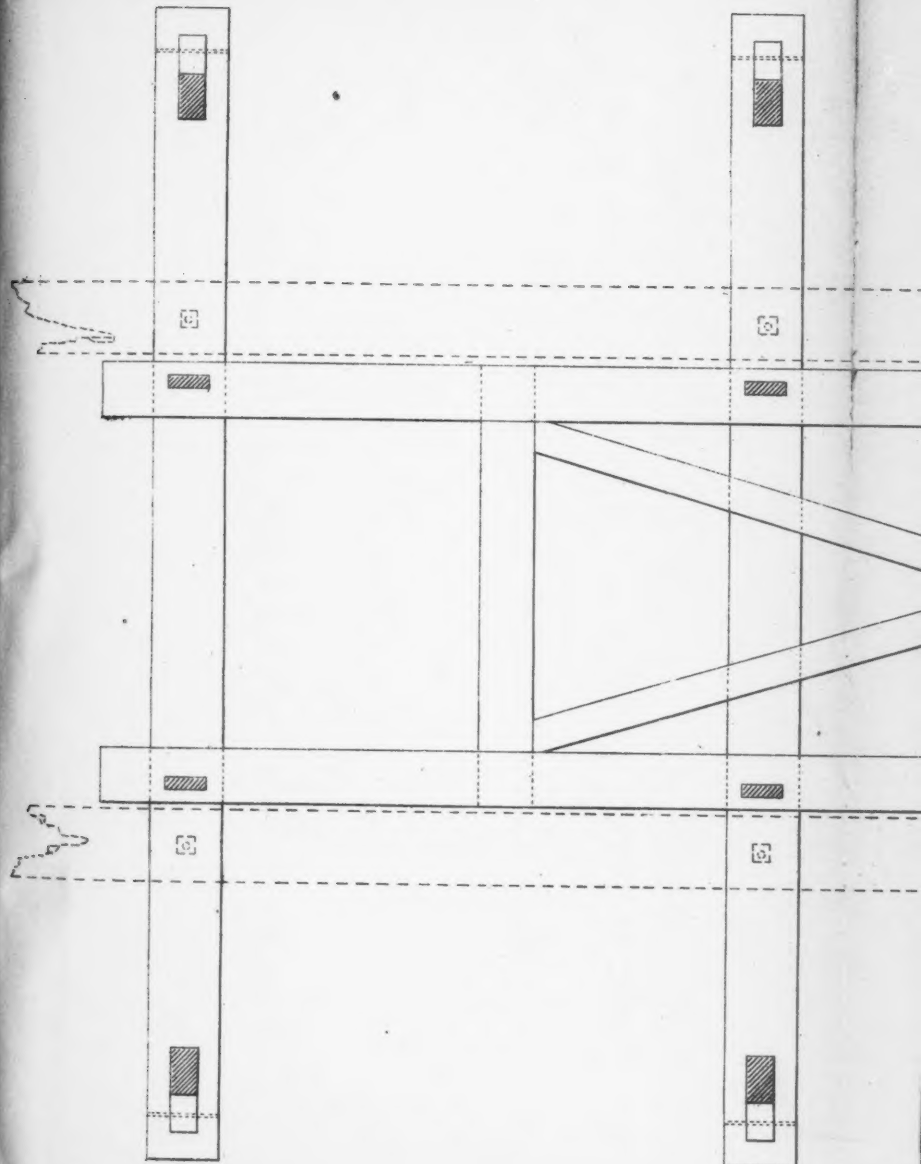
Fig. 3



Cross Section on ab

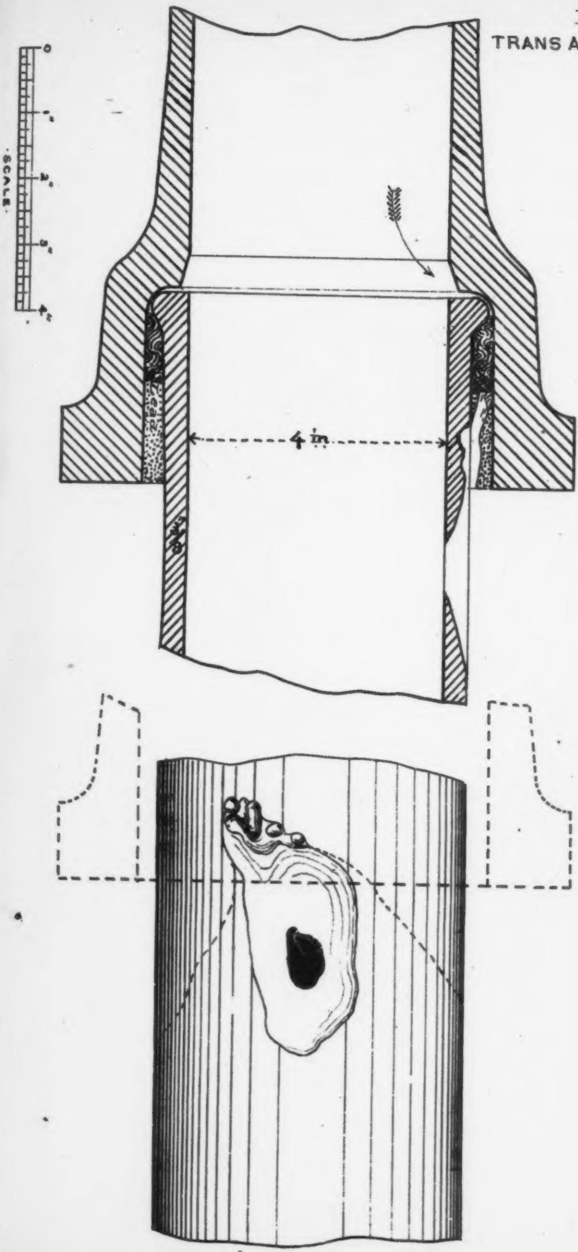
Fig 2





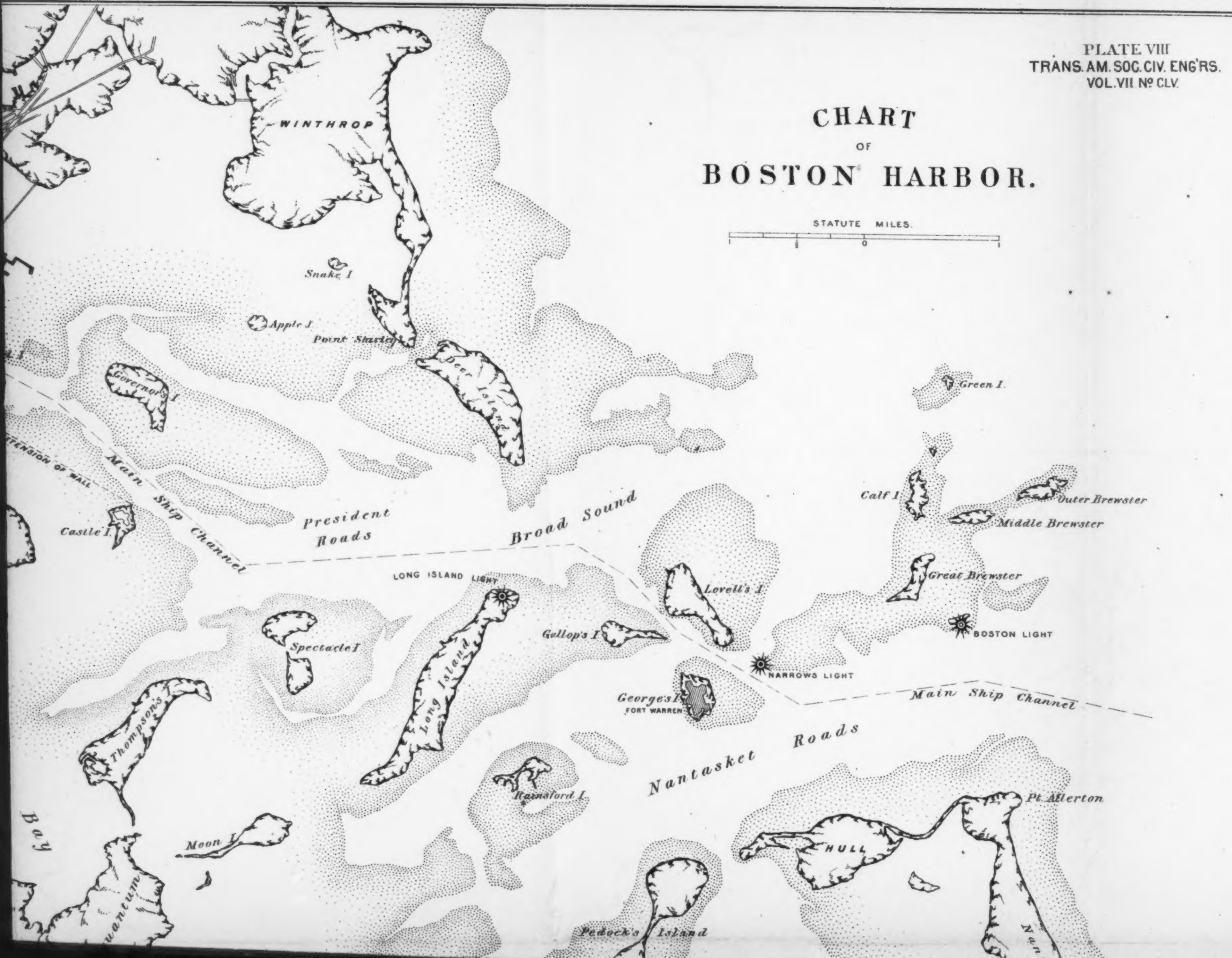
PLAN OF BOTTOM FRAME

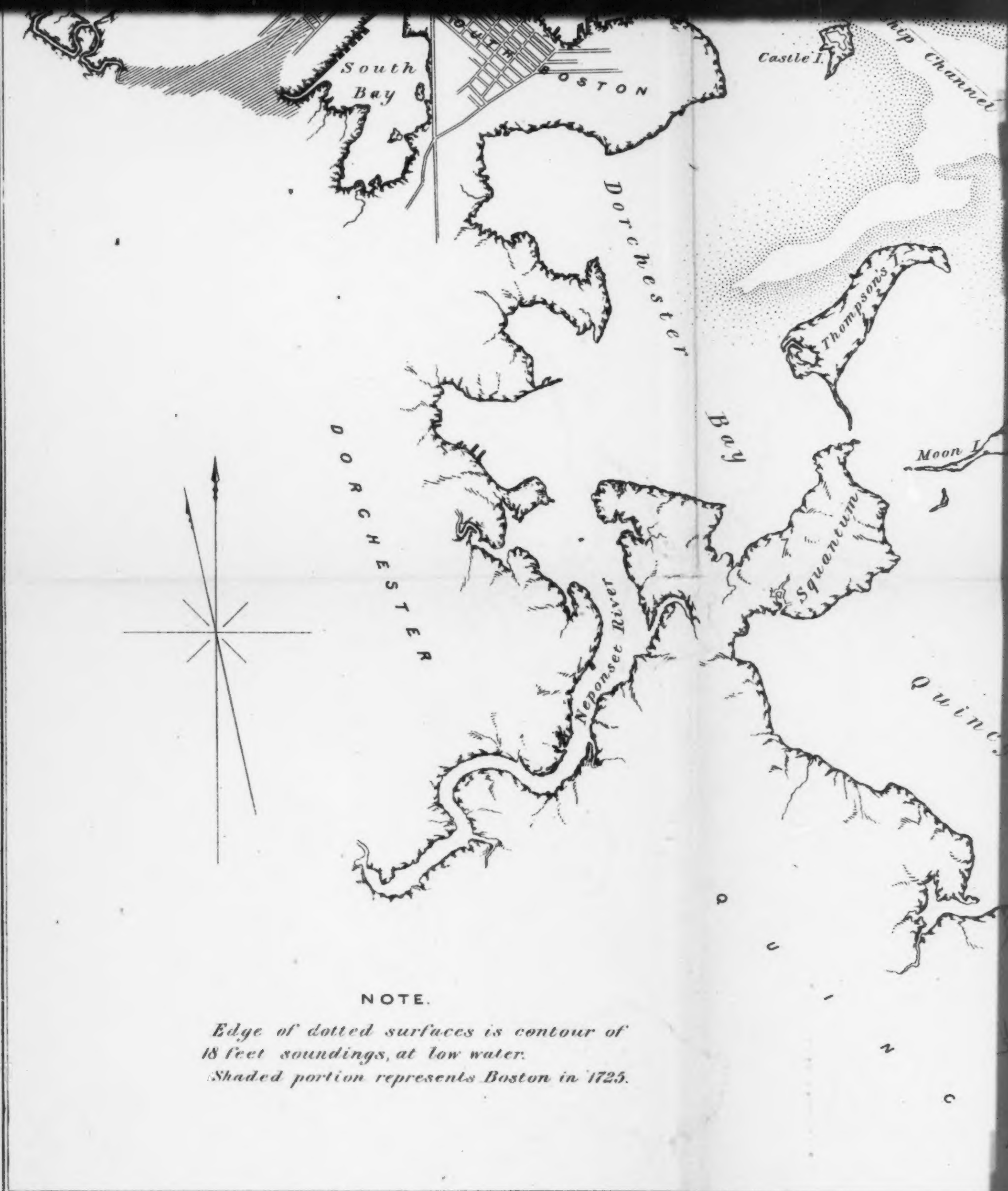
PLATE VII
TRANS AM. SOC. CIV. ENG'RS.
VOL. VII Nº 1

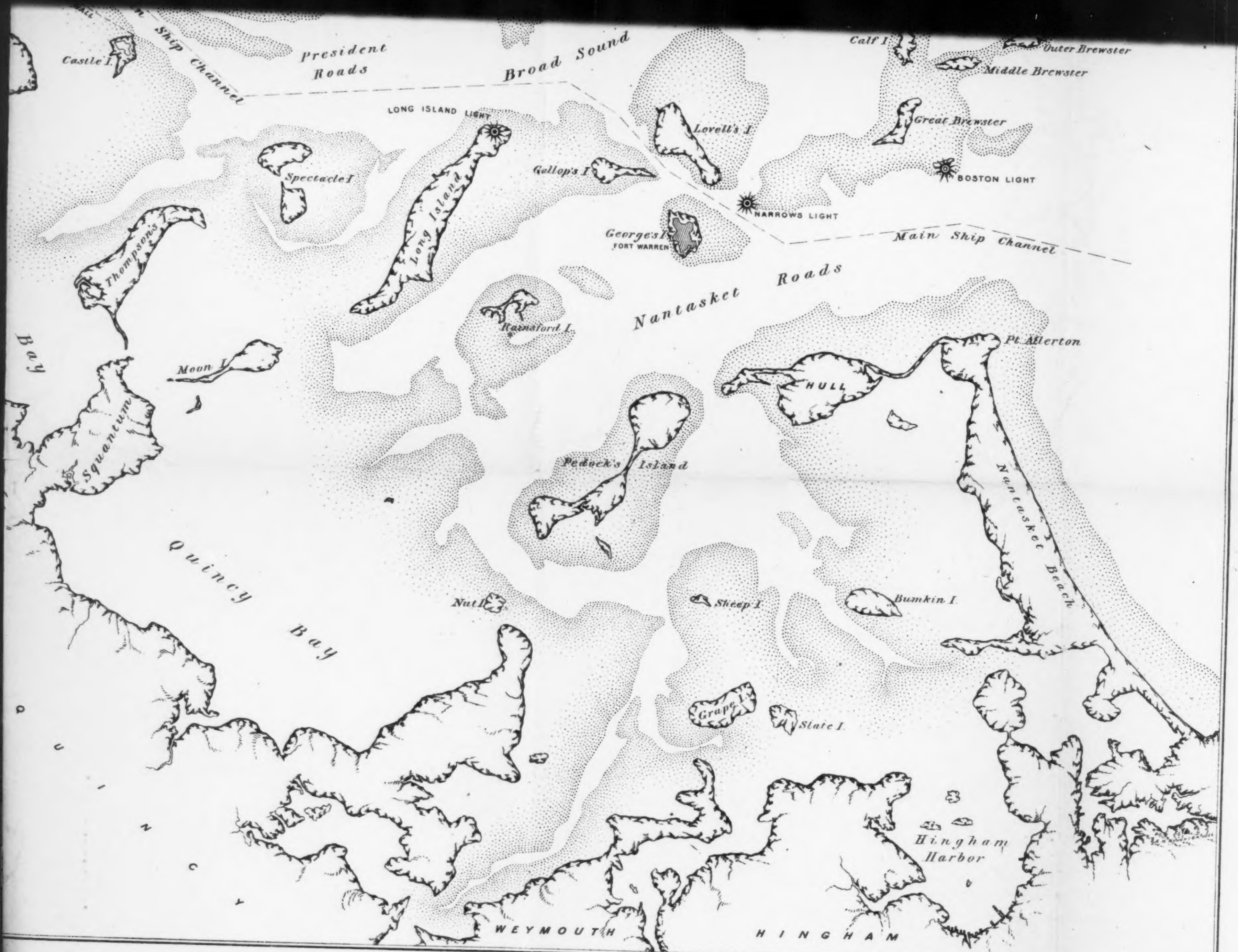


CHELSEA
Mystic River
CHARLESTOWN
Navy Yard
CAMBRIDGE
Charles River
BOSTON
Bird I.
PROPOSED EXTENSION OF WALL
FORT POINT CHANNEL
RECENT FILLING
SOUTH BOSTON
South Bay
Castle I.
Dorchester Bay
DORCHEST

CHART OF BOSTON HARBOR.




South Bay
SOUTH BOSTON
Castle I.
hip Channel
Dorchester Bay
Thompson's
Moon I.
Squantum
DORCHESTER
Neponset River
Quincy
QUINC
NOTE.
Edge of dotted surfaces is contour of 18 feet soundings, at low water.
Shaded portion represents Boston in 1725.



Castle I.
Ship Channel
President Roads
Broad Sound
Calf I.
Outer Brewster
Middle Brewster
LONG ISLAND LIGHT
Lovell's I.
Great Brewster
Spectacle I.
Long Island
Gallop's I.
BOSTON LIGHT
NARROWS LIGHT
George's I.
FORT WARREN
Main Ship Channel
Thompson's
Nantasket Roads
Rainsford I.
Bay
Moon I.
Pt. Allerton
HULL
Squantum
Pedock's Island
Nantasket Beach
Quincy Bay
Nut I.
Sheep I.
Bumkin I.
Grape I.
Slate I.
QUINCY
Hingham Harbor
WEYMOUTH
HINGHAM

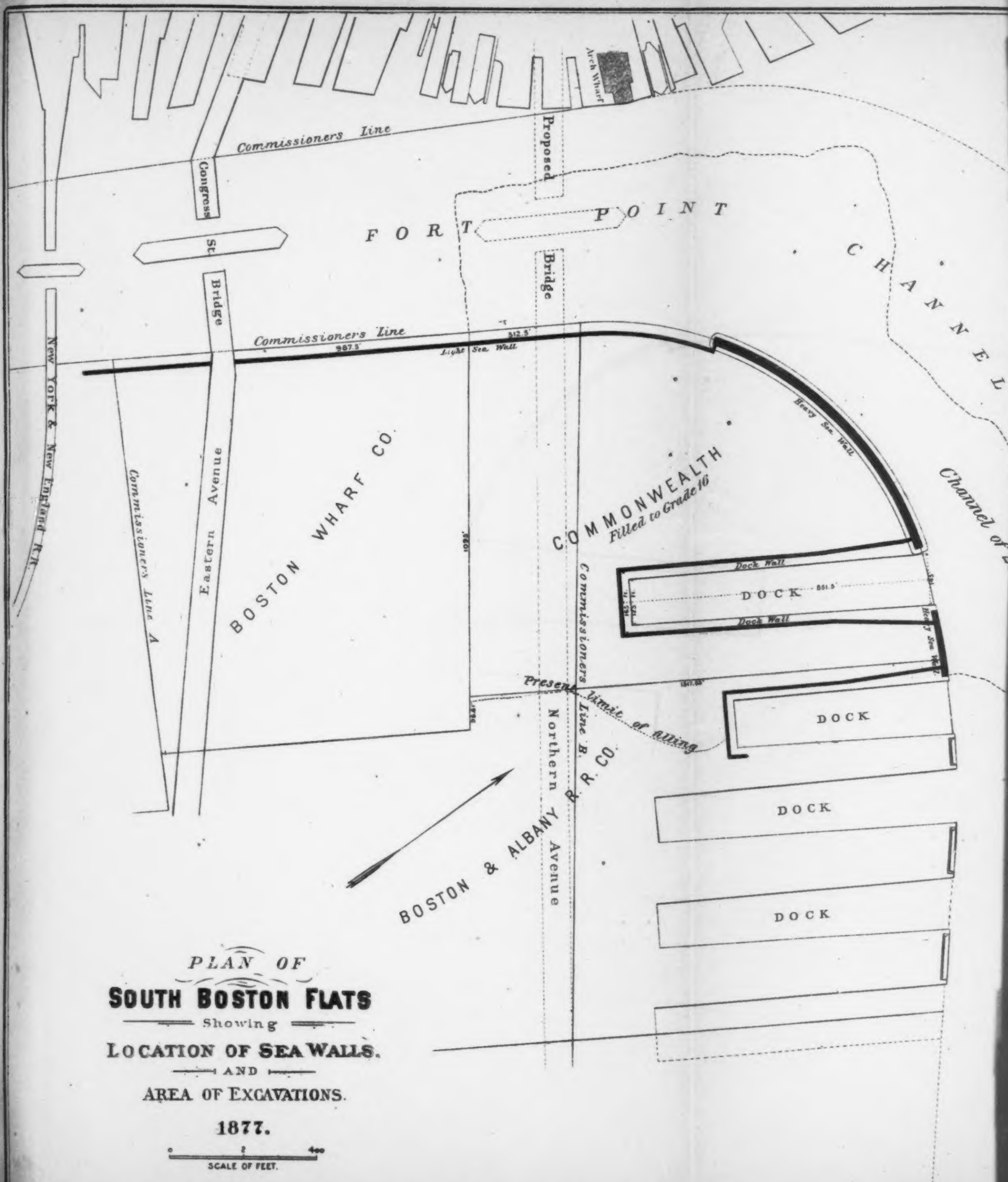
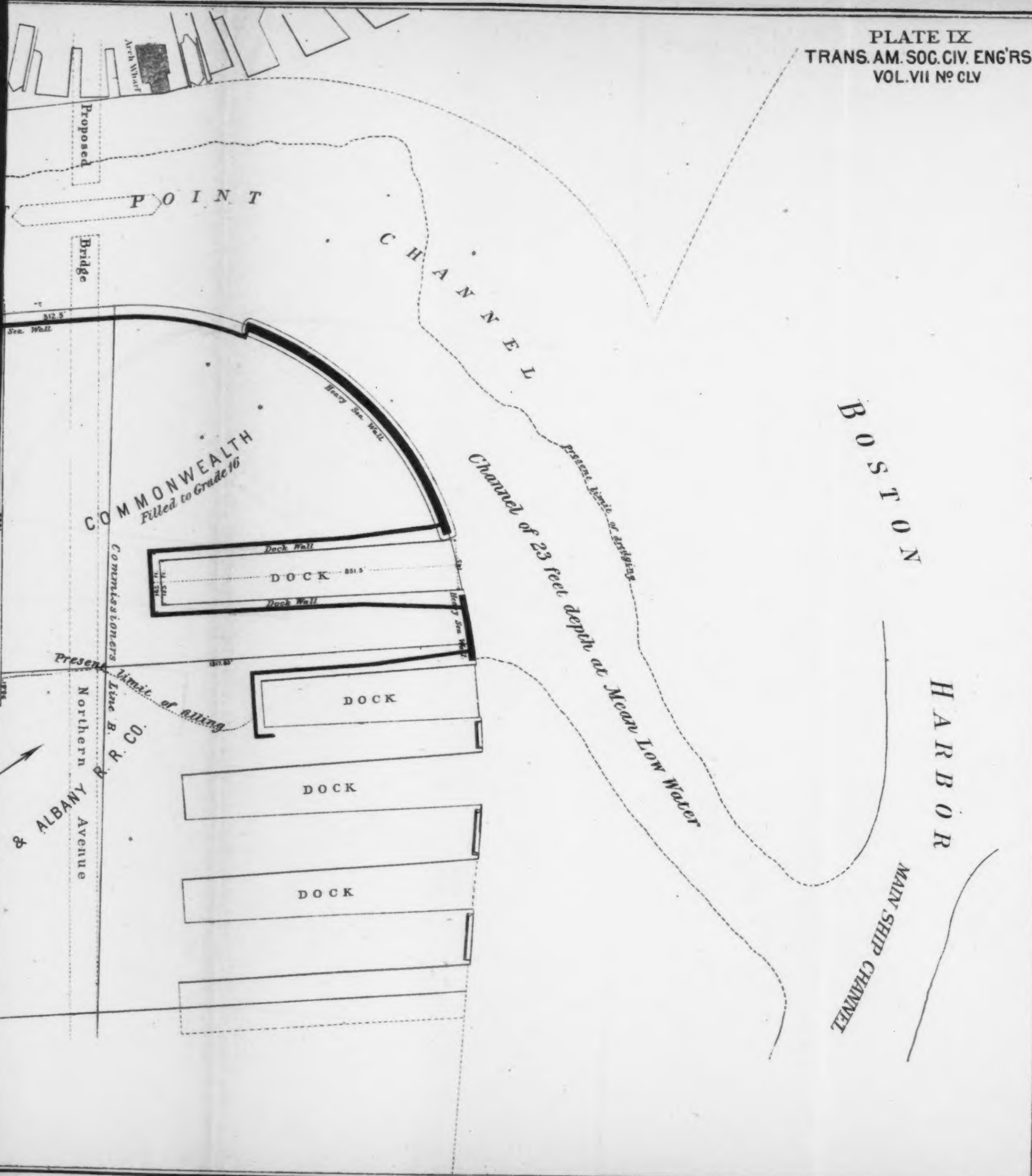

Arch Wharf
Commissioners Line
Congress
St
Bridge
Proposed
Bridge
FORT POINT CHANNEL
Channel of
New York & New England R.R.
Commissioners Line
987.5'
512.5'
Light Sea Wall
Heavy Sea Wall
Commissioners Line A
Eastern Avenue
BOSTON WHARF CO.
COMMONWEALTH
Filled to Grade 16
Dock Wall
DOCK
851.5'
Dock Wall
Heavy Sea Wall
Present limit of filling
DOCK
Commissioners Line B.
Northern Avenue
BOSTON & ALBANY R.R. CO.
DOCK
DOCK
PLAN OF
SOUTH BOSTON FLATS
Showing
LOCATION OF SEA WALLS.
AND
AREA OF EXCAVATIONS.
1877.
SCALE OF FEET.

PLATE IX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII Nº CLV



DOCK ON THE FLATS OF THE COMMONW

Fig. 1.

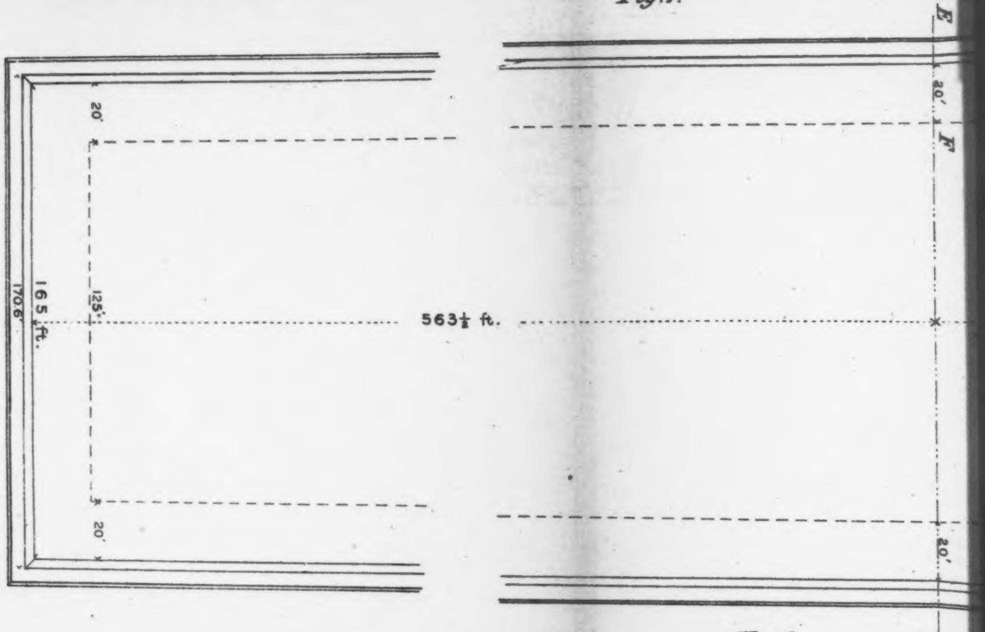
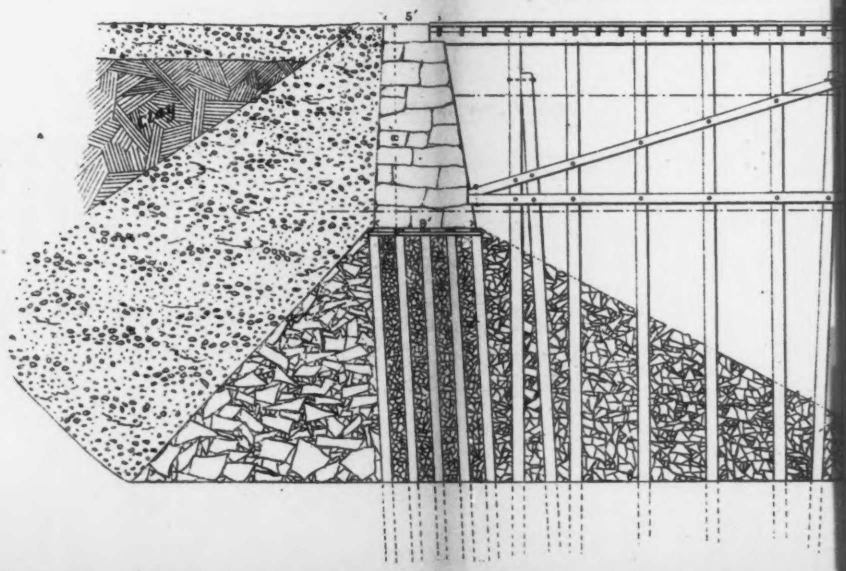


Fig. 2.

SECTION THROUGH C



LATS OF THE COMMONWEALTH.

Fig. 1.

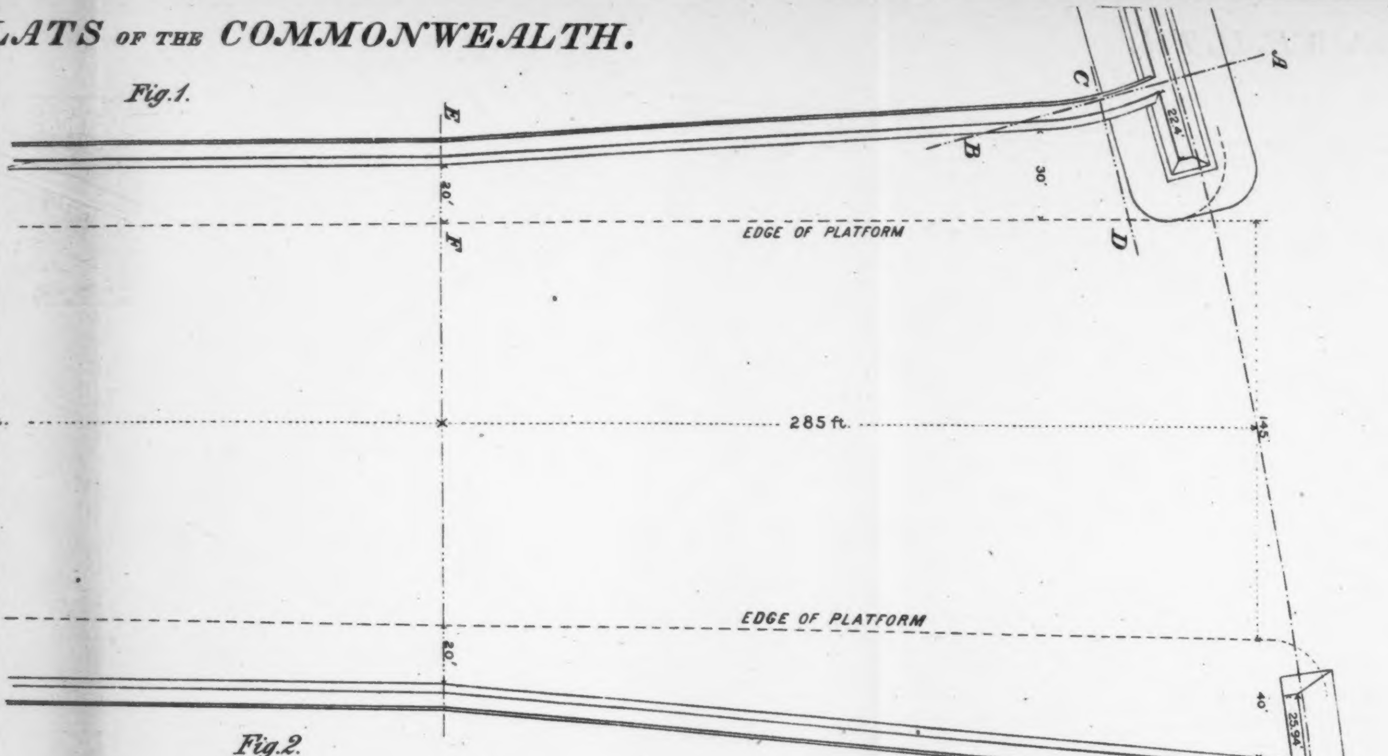
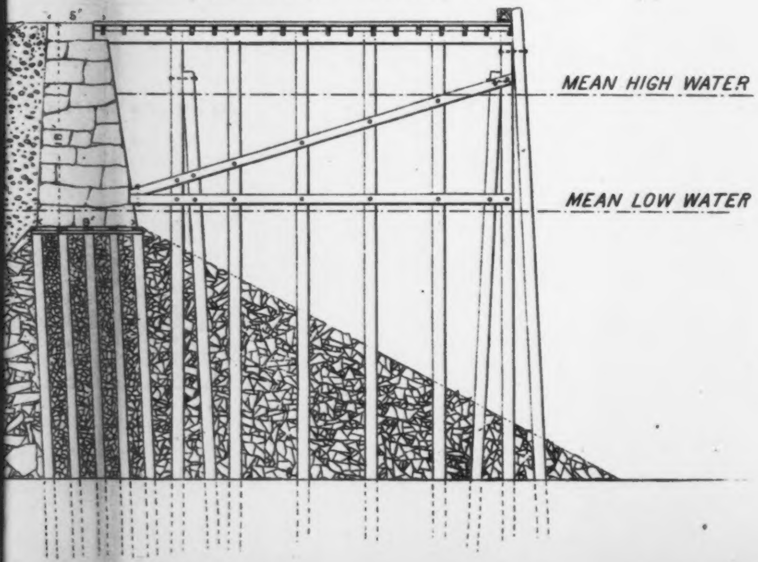


Fig. 2.

SECTION THROUGH C-D.



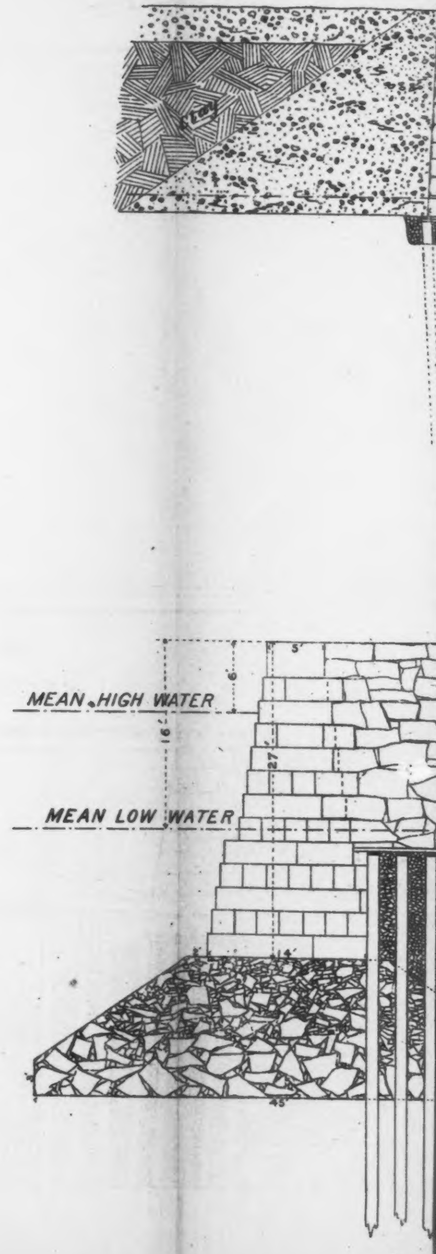
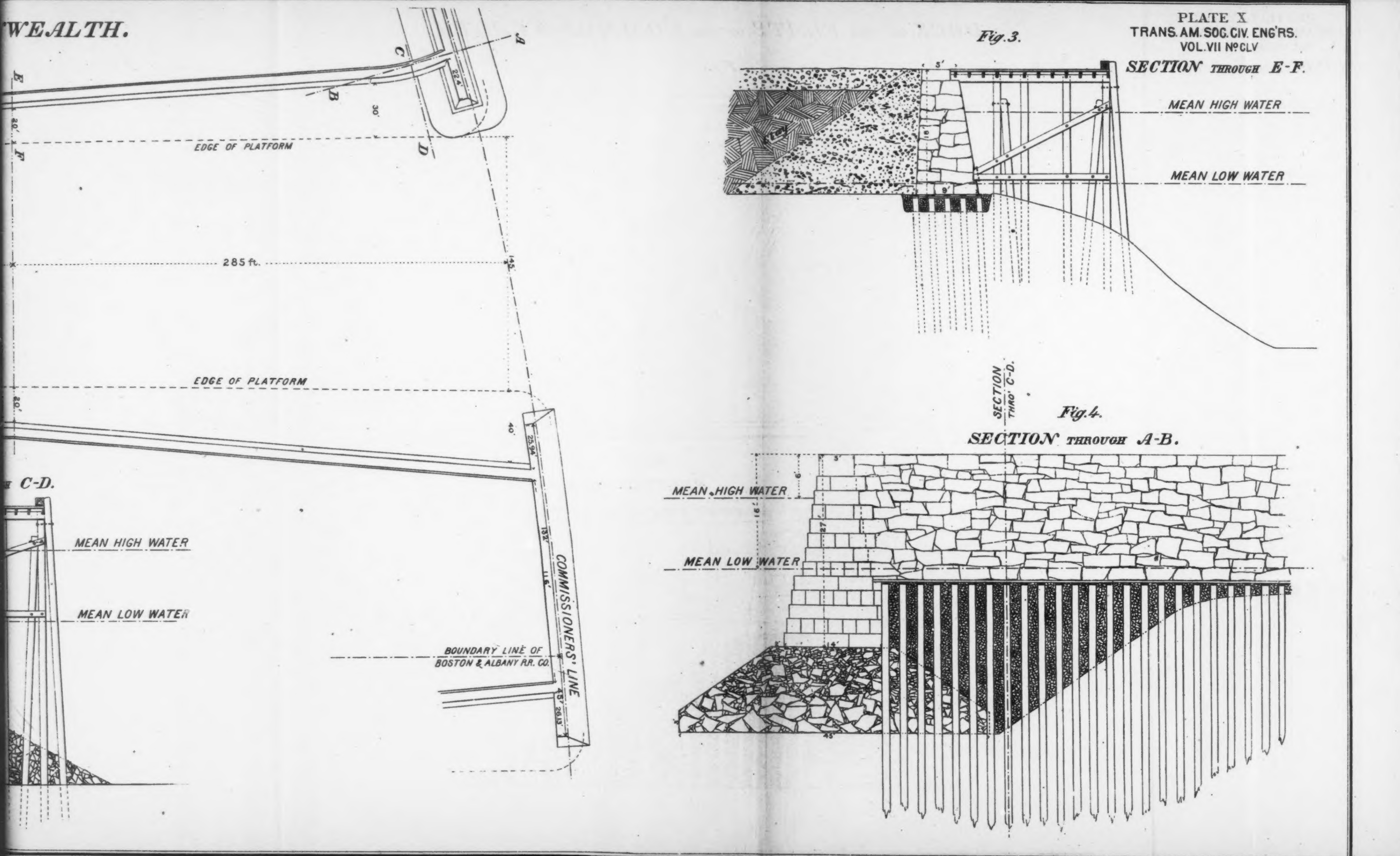


PLATE X
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No CLV



IMPROVEMENT OF SOUTH BOSTON FLATS.

HEAVY SEA WALL

WEST OF DOCKS.

BUILT IN 1875-6

SCALE

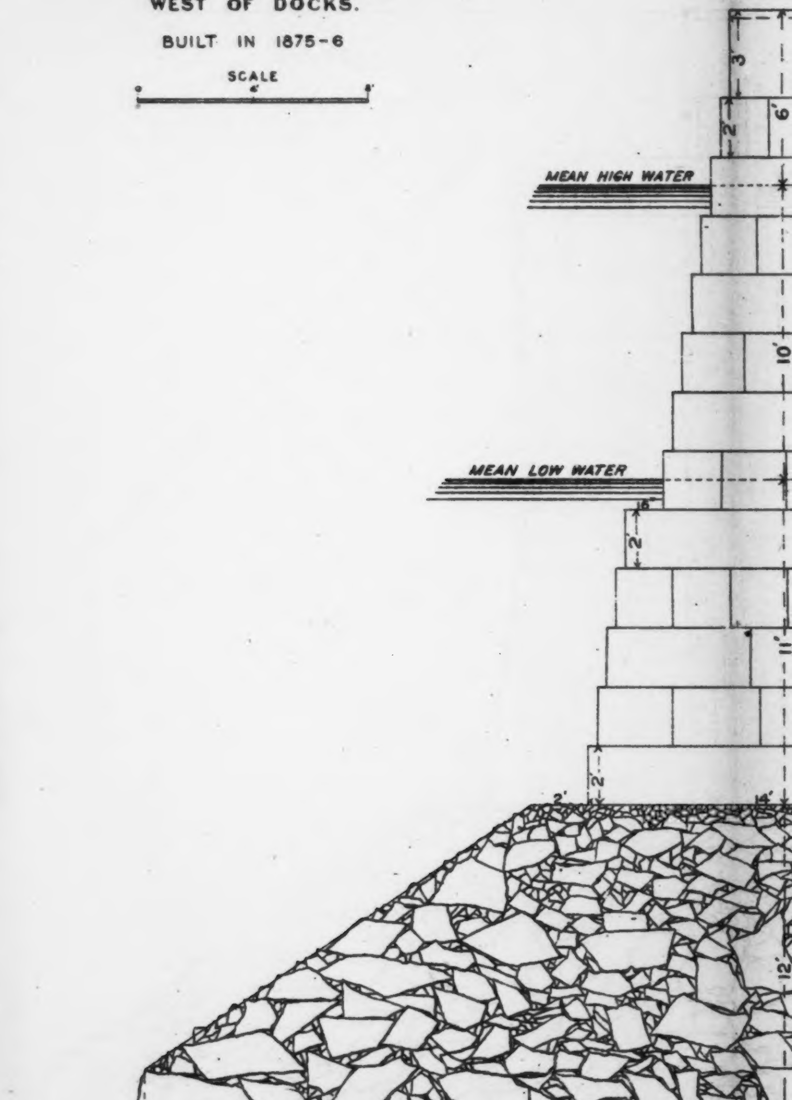
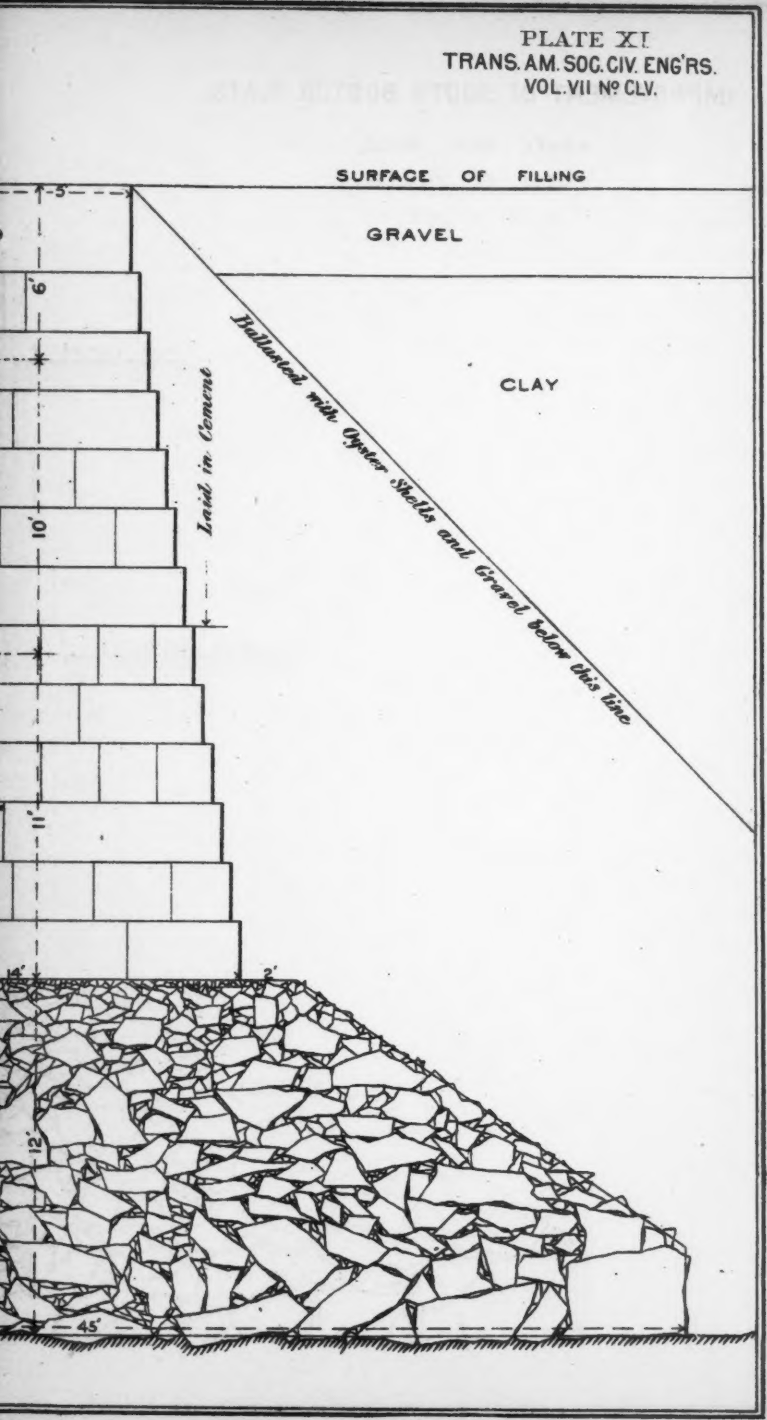


PLATE XI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII Nº CLV.



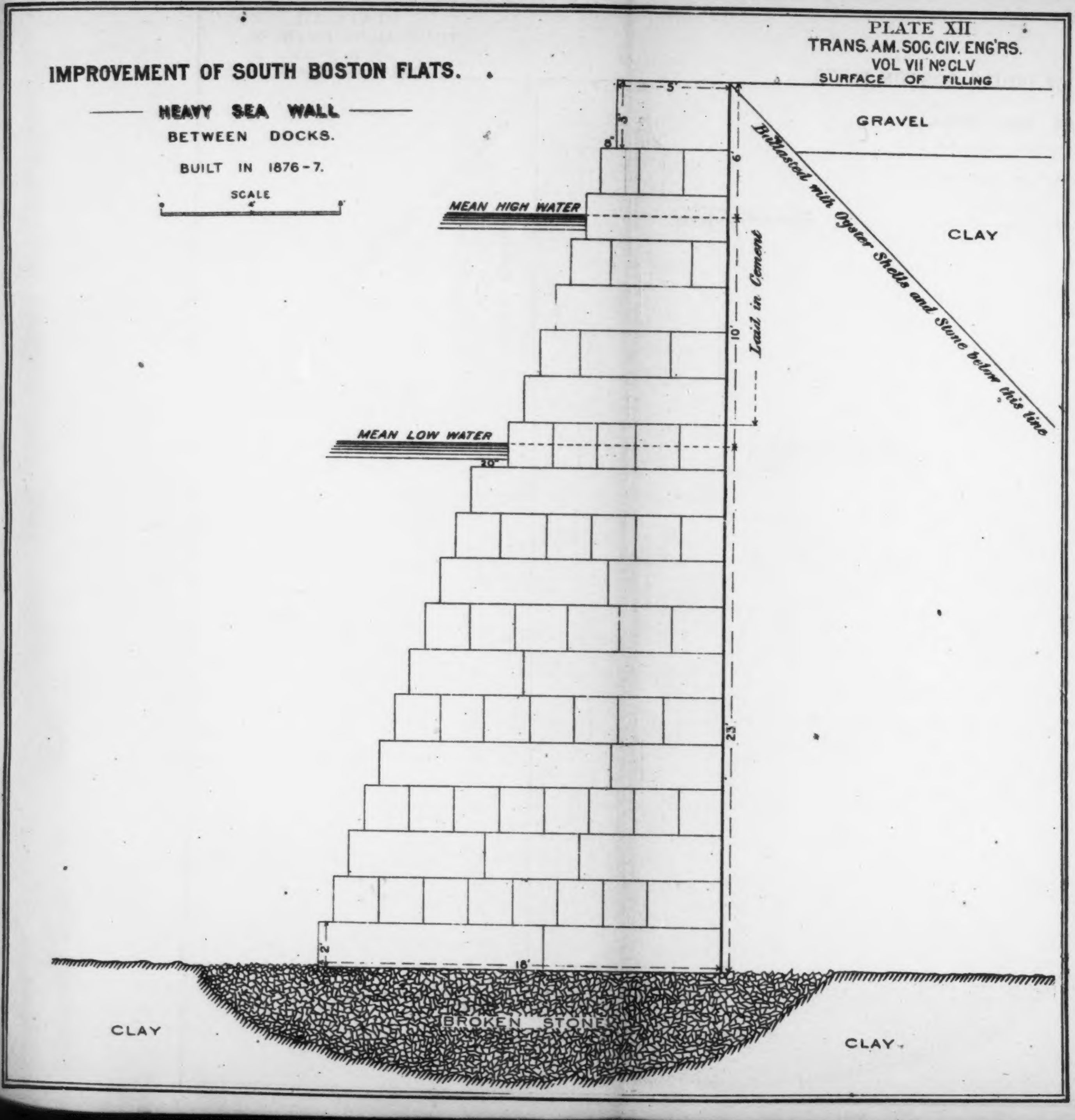
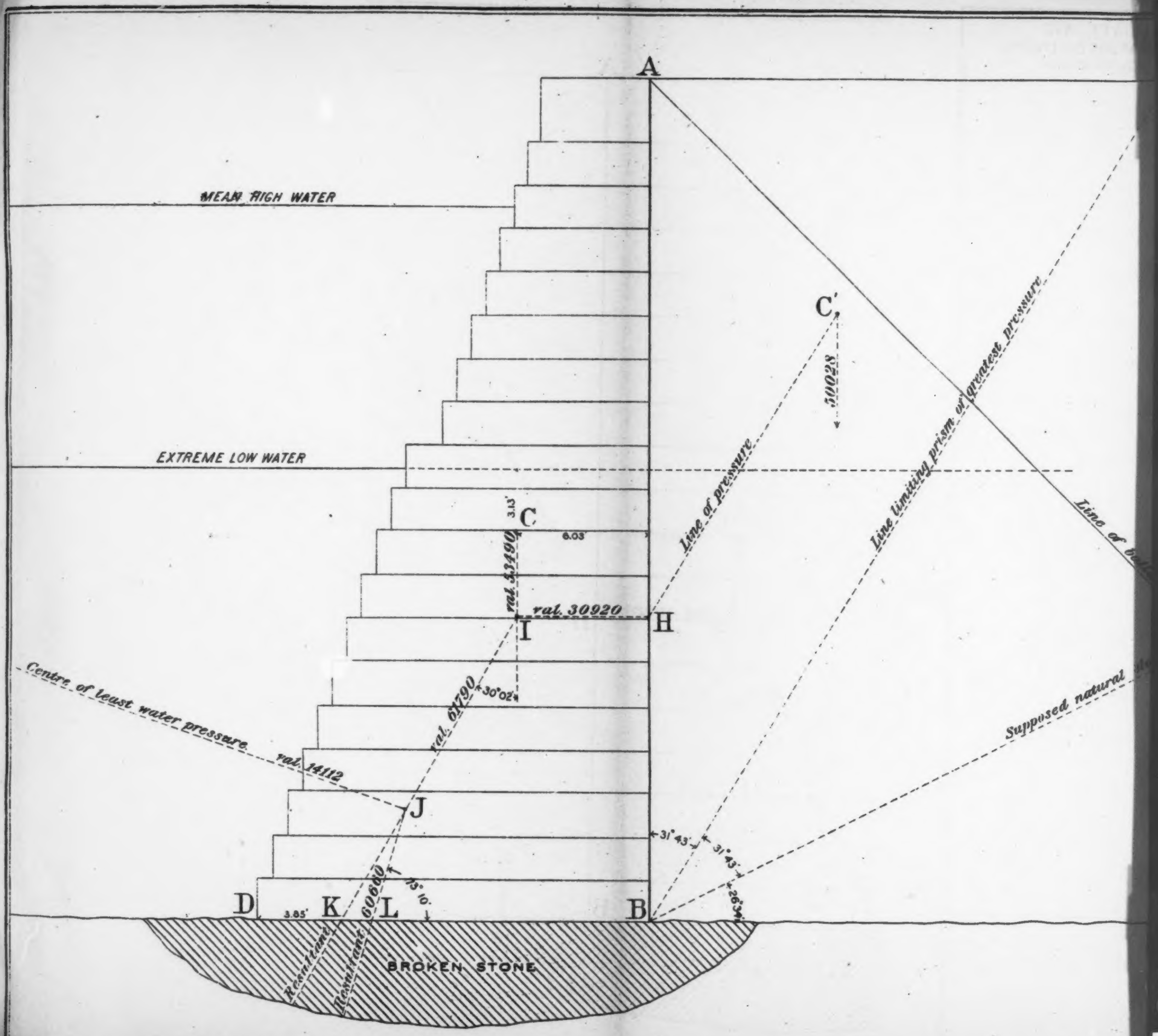
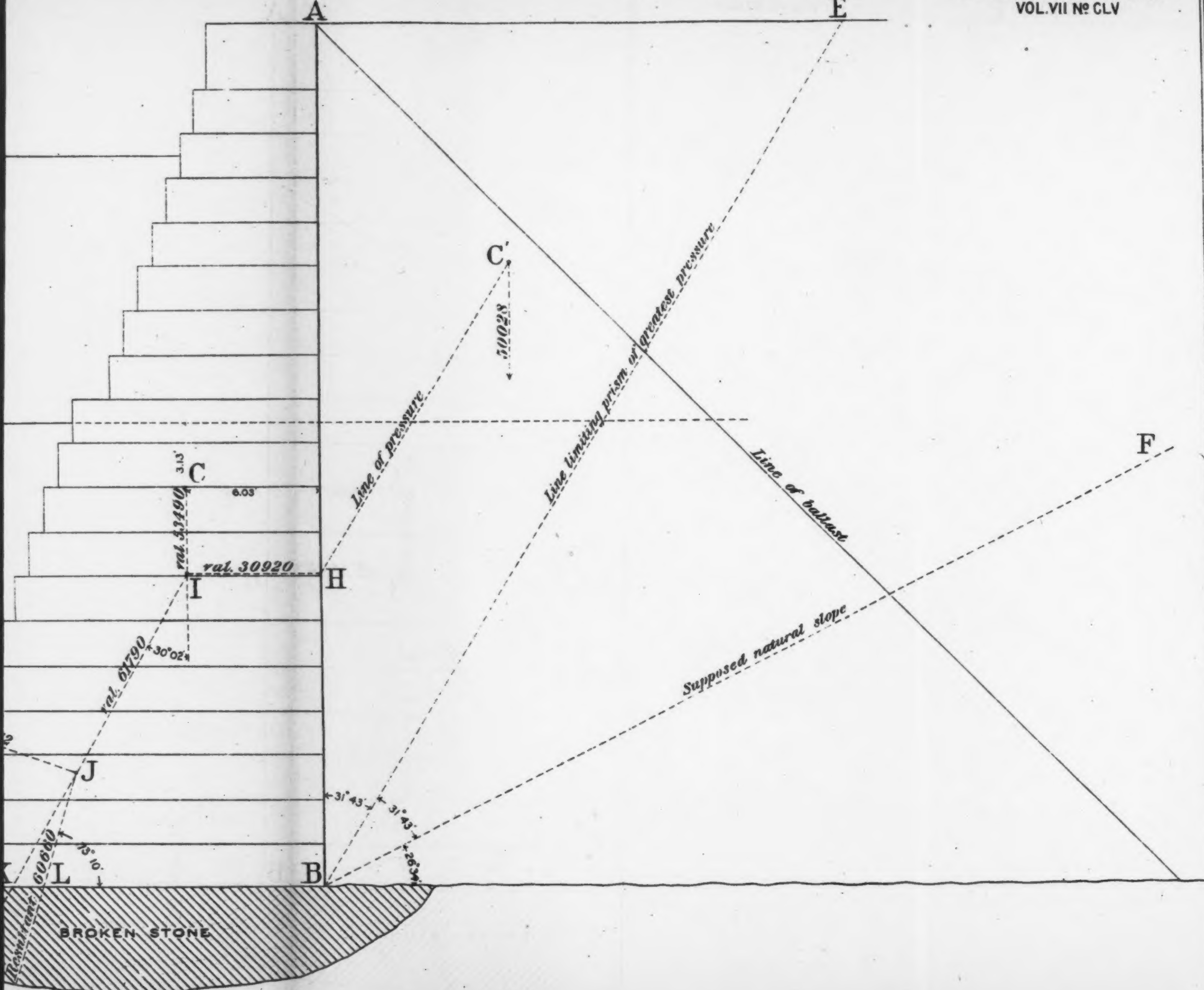
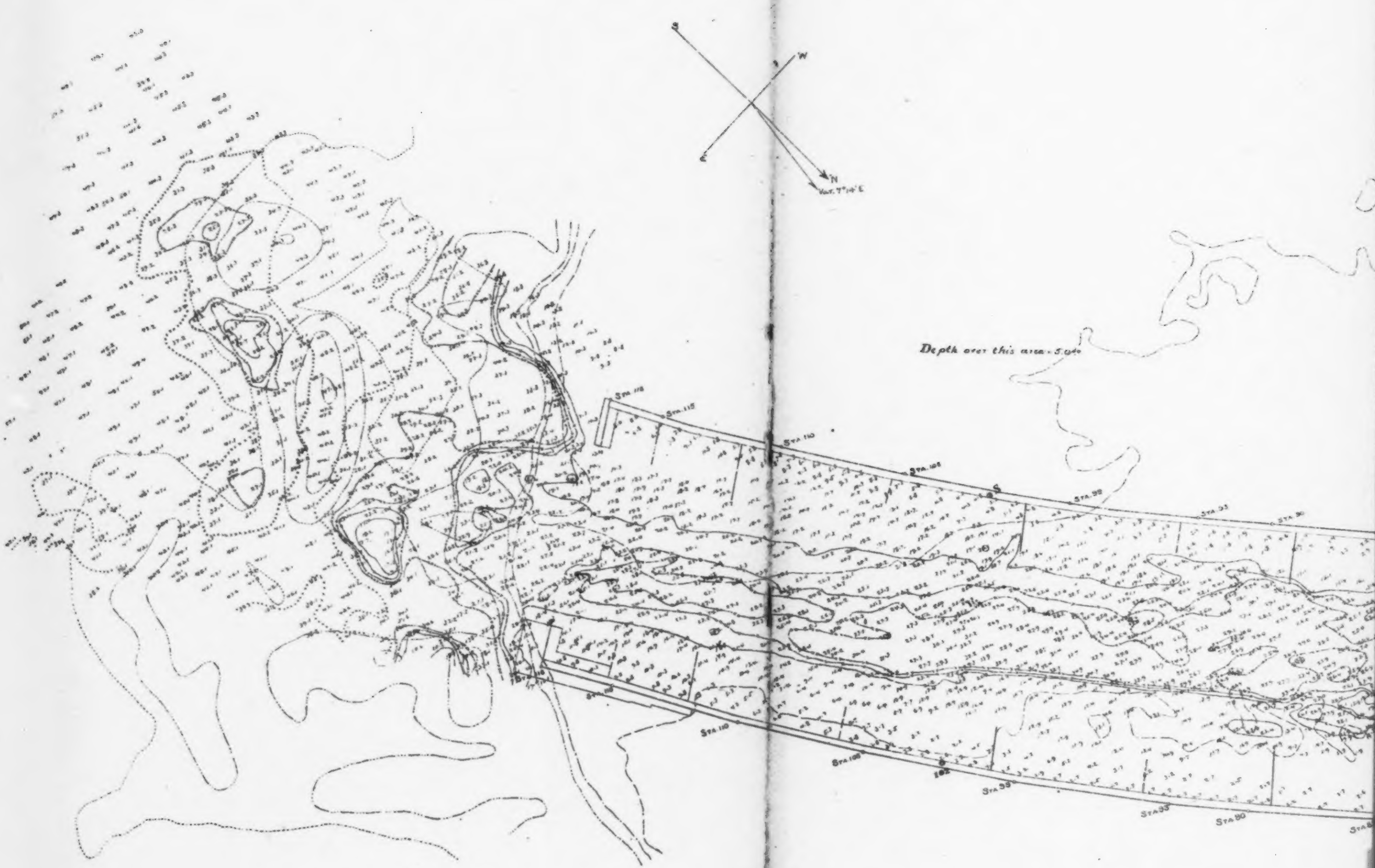


PLATE XII
TRANS. AM. SOC. CIV. ENG'RS.
VOL VII No. CLV
IMPROVEMENT OF SOUTH BOSTON FLATS.
HEAVY SEA WALL
BETWEEN DOCKS.
BUILT IN 1876-7.
SCALE
SURFACE OF FILLING
GRAVEL
CLAY
Ballasted with Oyster Shells and Stone below this line
Laid in Cement
MEAN HIGH WATER
MEAN LOW WATER
5'
3'
8'
6'
10'
20'
23'
2'
18'
BROKEN STONE
CLAY
CLAY



A
MEAN HIGH WATER
EXTREME LOW WATER
C'
30028
C
3.13'
6.03
val. 33490
val. 30920
H
I
Line of pressure
Line limiting prism of greatest pressure
Supposed natural
Centre of least water pressure
val. 14112
val. 61790
30°02'
J
31°43'
31°43'
26°34'
75°10'
D
3.85'
K
60680
L
B
Resultant
Resultant
BROKEN STONE


A
E
C'
50028
Line of pressure
Line limiting prism of greatest pressure
Line of ballast
F
C
3.13'
6.03'
val. 33490
val. 30920
H
I
30°02'
val. 61790
Supposed natural slope
J
31°43'
31°43'
26°34'
15°10'
Resultant 60660
K
L
B
BROKEN STONE


S
W
E
N
Depth over this area = 5.0ft
Depth = 5.0ft

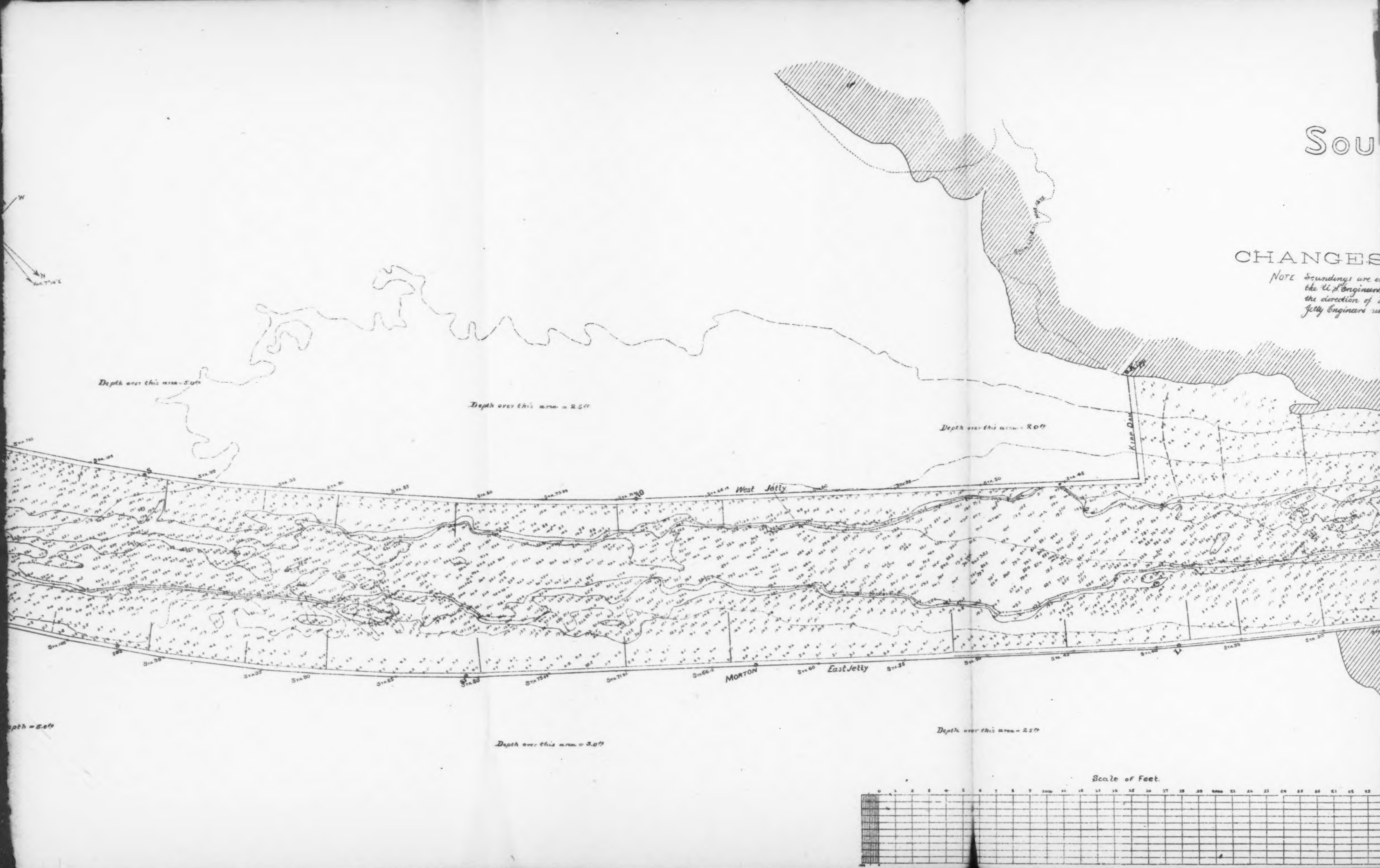
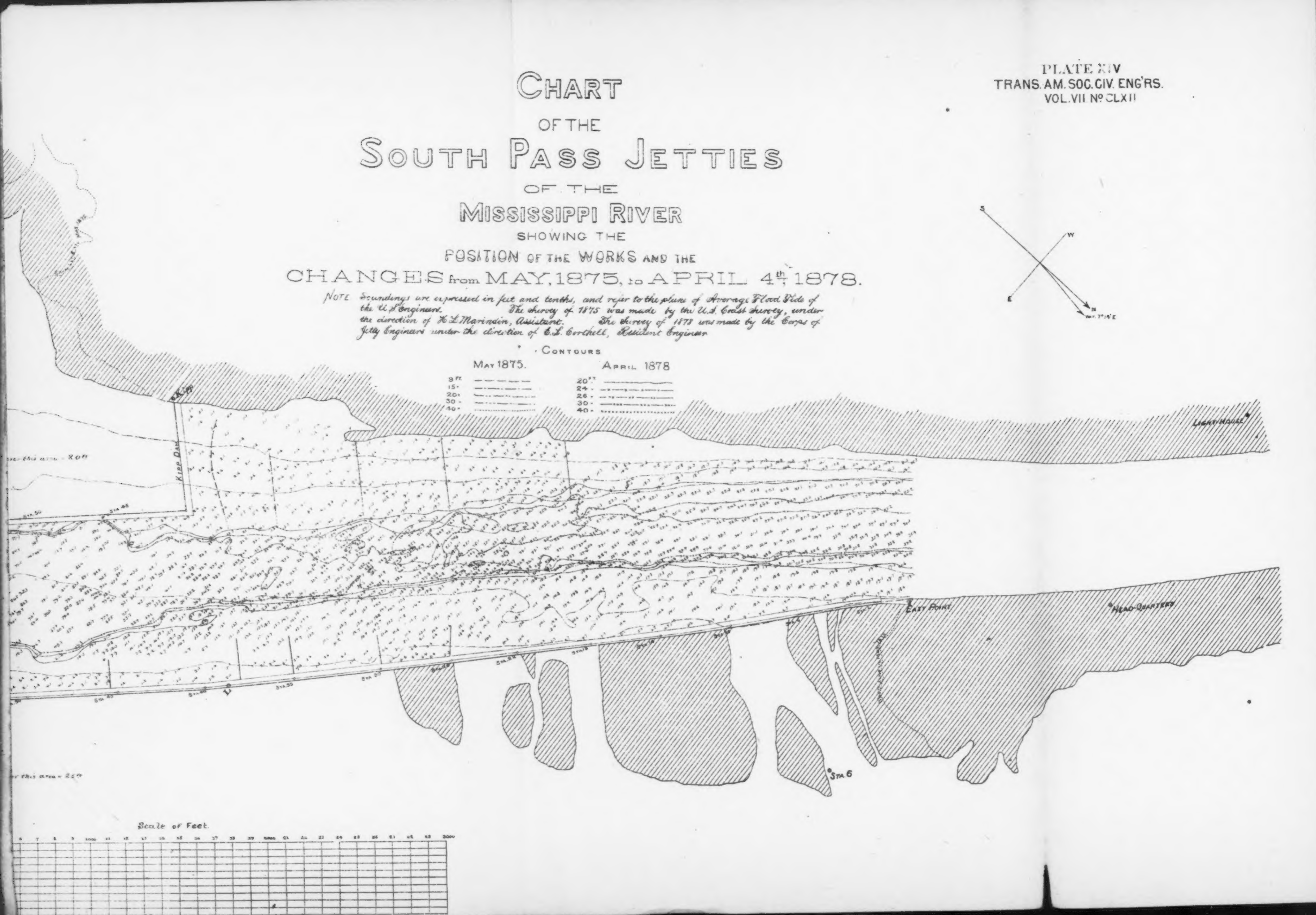
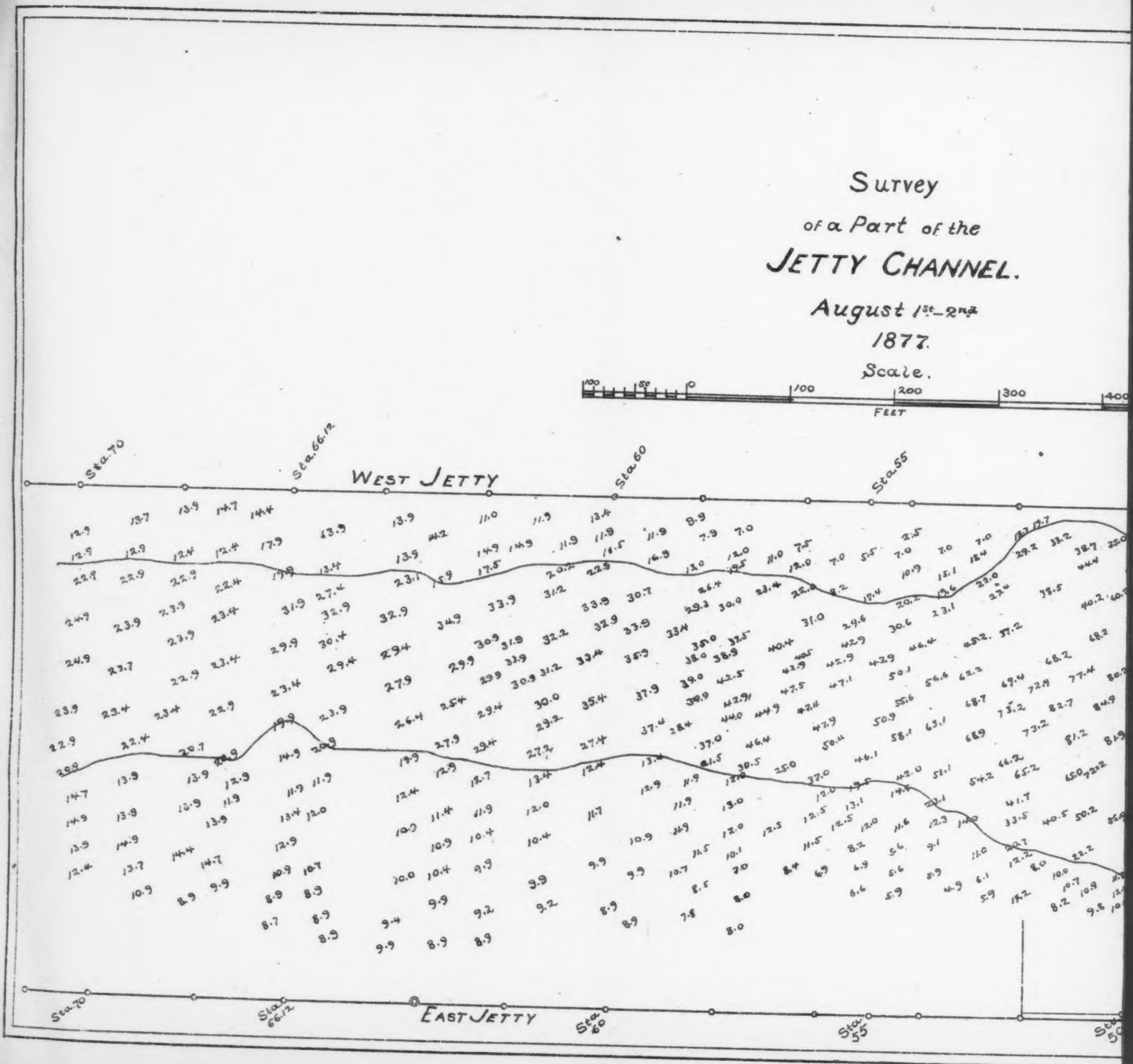

SOU
CHANGES
Depth over this area = 5.0 ft
Depth over this area = 2.5 ft
Depth over this area = 2.0 ft
West Jetty
East Jetty
MORTON
Depth over this area = 3.0 ft
Depth over this area = 2.5 ft
Scale of Feet

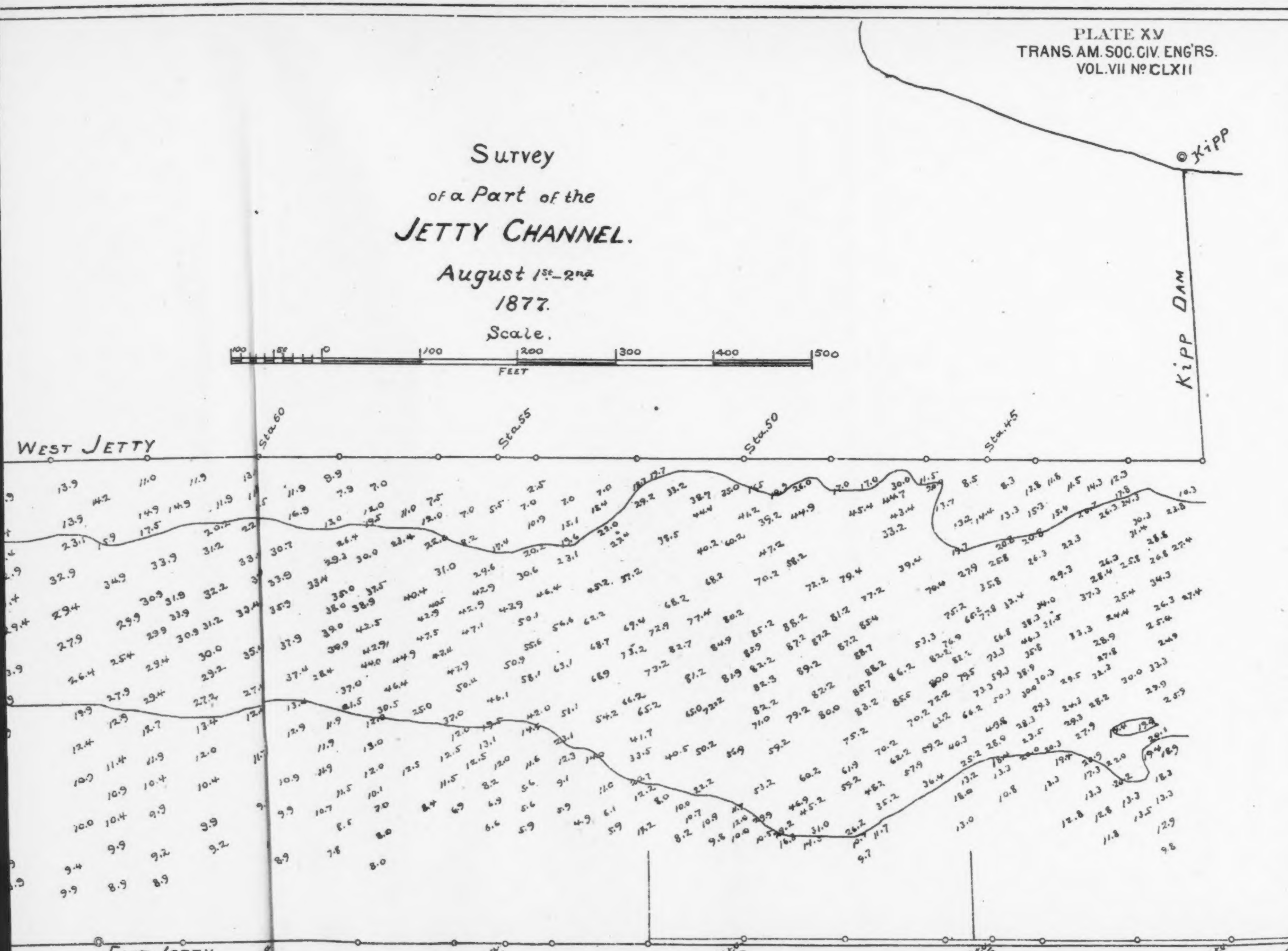
PLATE XIV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No. CLXII

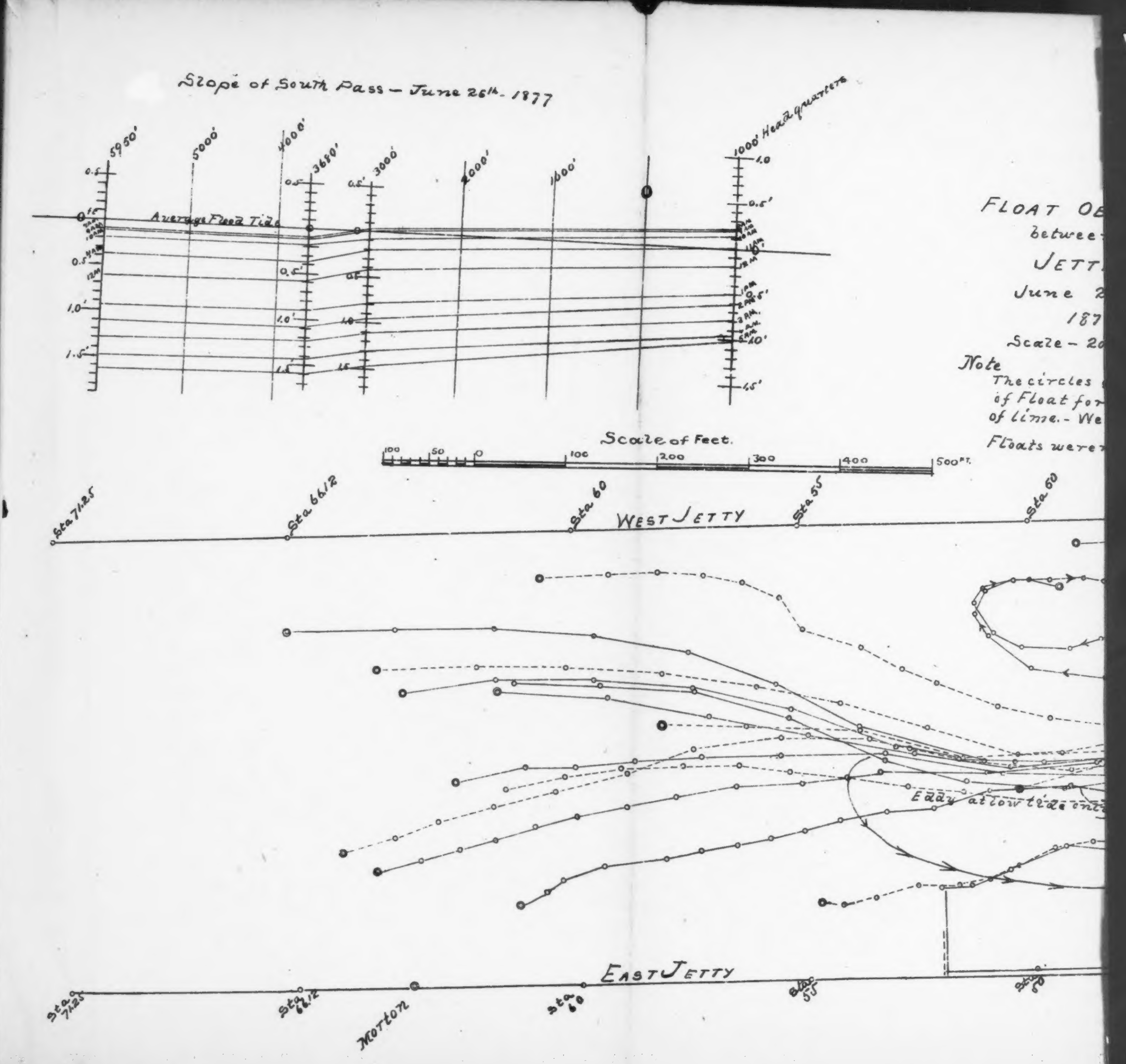


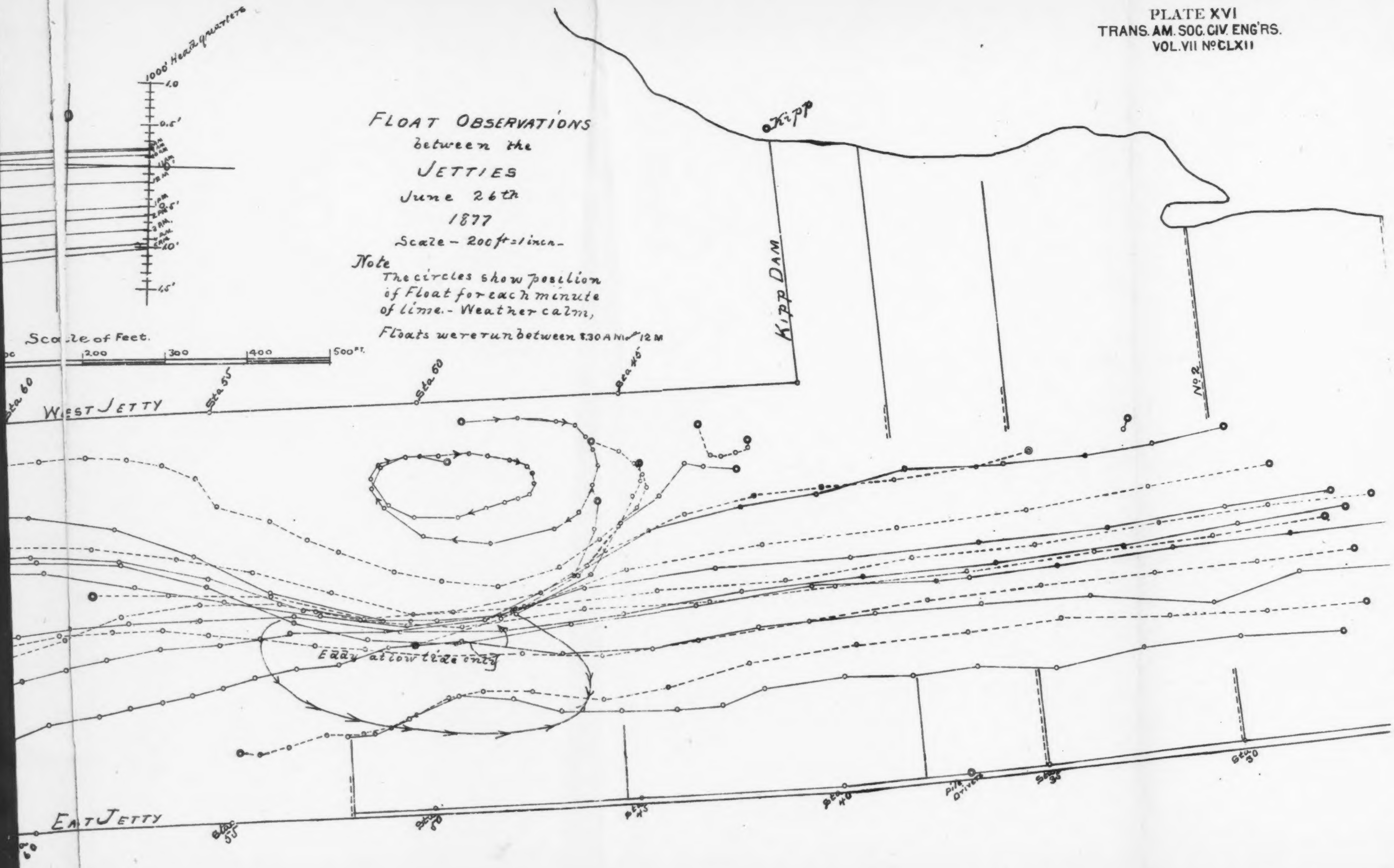


Survey
of a Part of the
JETTY CHANNEL.
August 1st–2nd
1877.
Scale.
100 50 0 100 200 300 400
FEET
Sta. 70
Sta. 66.12
WEST JETTY
Sta. 60
Sta. 55
Sta. 70
Sta. 66.12
EAST JETTY
Sta. 60
Sta. 55
Sta. 50

PLATE XV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No CLXII




Slope of South Pass - June 26th 1877
5950'
5000'
4000'
3680'
3000'
2000'
1600'
1000' Headquarters
Average Flood Tide
Scale of Feet.
100 50 0 100 200 300 400 500 FT.
FLOAT OB
betwee
JETT
June 2
187
Scale - 20
Note
The circles
of Float for
of line. - We
Floats were
Sta 71.25
Sta 66.12
Sta 60
Sta 55
Sta 50
WEST JETTY
Eddy at low tide only
EAST JETTY
Morton


FLOAT OBSERVATIONS
between the
JETTIES
June 26th
1877
Scale – 200 ft = 1 inch.
Note
The circles show position
of Float for each minute
of time. – Weather calm,
Floats were run between 8.30 A.M. & 12 M.
1000' Headquarters
Scale of Feet.
200
300
400
500 FT.
Kipp
Kipp Dam
No. 2
West Jetty
Sta 60
Sta 55
Sta 60
Sta 45
Eddy at low tide only
East Jetty
Sta 55
Sta 50
Sta 45
Sta 40
Pile Driver
Sta 35
Sta 30

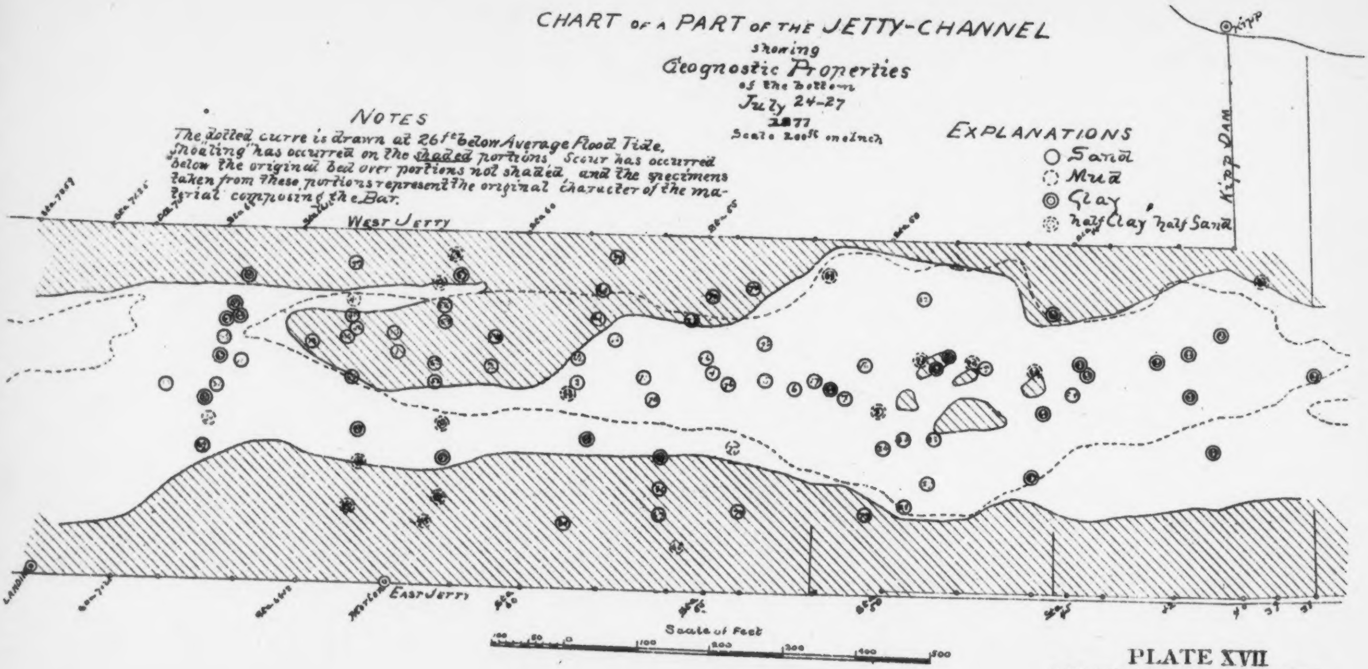
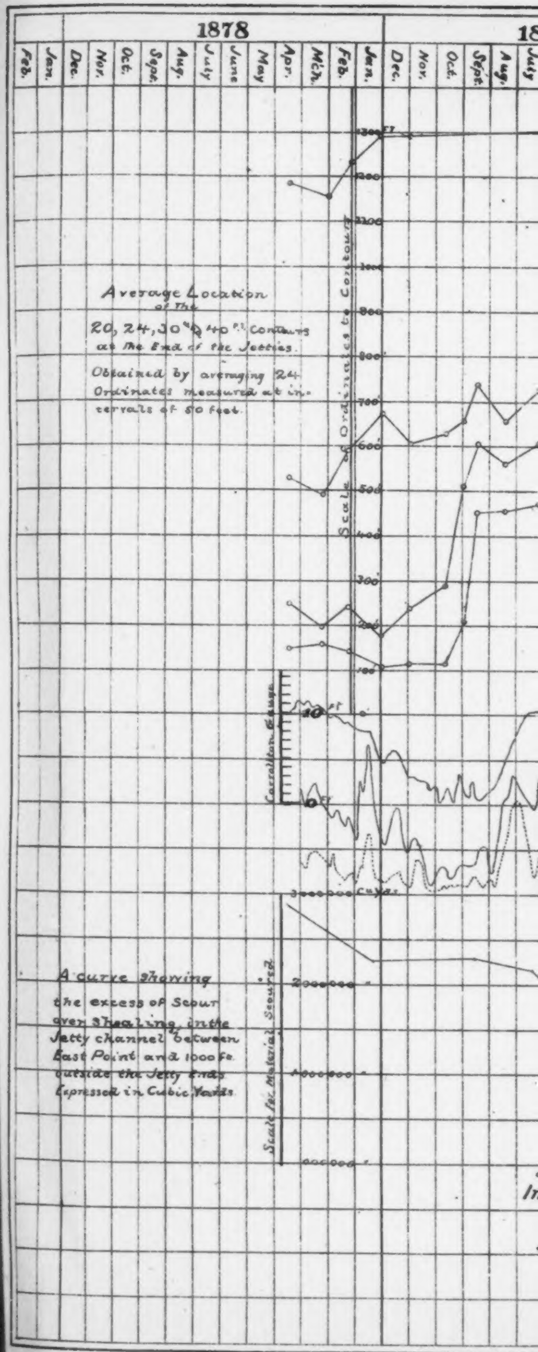


PLATE XVII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No CLXII


1878
Feb.
Jan.
Dec.
Nov.
Oct.
Sept.
Aug.
July
June
May
Apr.
Mch.
Feb.
Jan.
Dec.
Nov.
Oct.
Sept.
Aug.
July
Average Location of the 20, 24, 30 & 40 Ft. Contours at the End of the Jetties.
Obtained by averaging 24 Ordinates measured at intervals of 50 feet.
Scale of Ordinates to Contours
Carrollton Gauge
A curve showing the excess of Scour over Shoaling, in the Jetty channel between East Point and 1000 ft. outside the Jetty Ends Expressed in Cubic Yards.
Scale for Material Scoured
3000000 Cu. yds.
2000000
1000000
000000

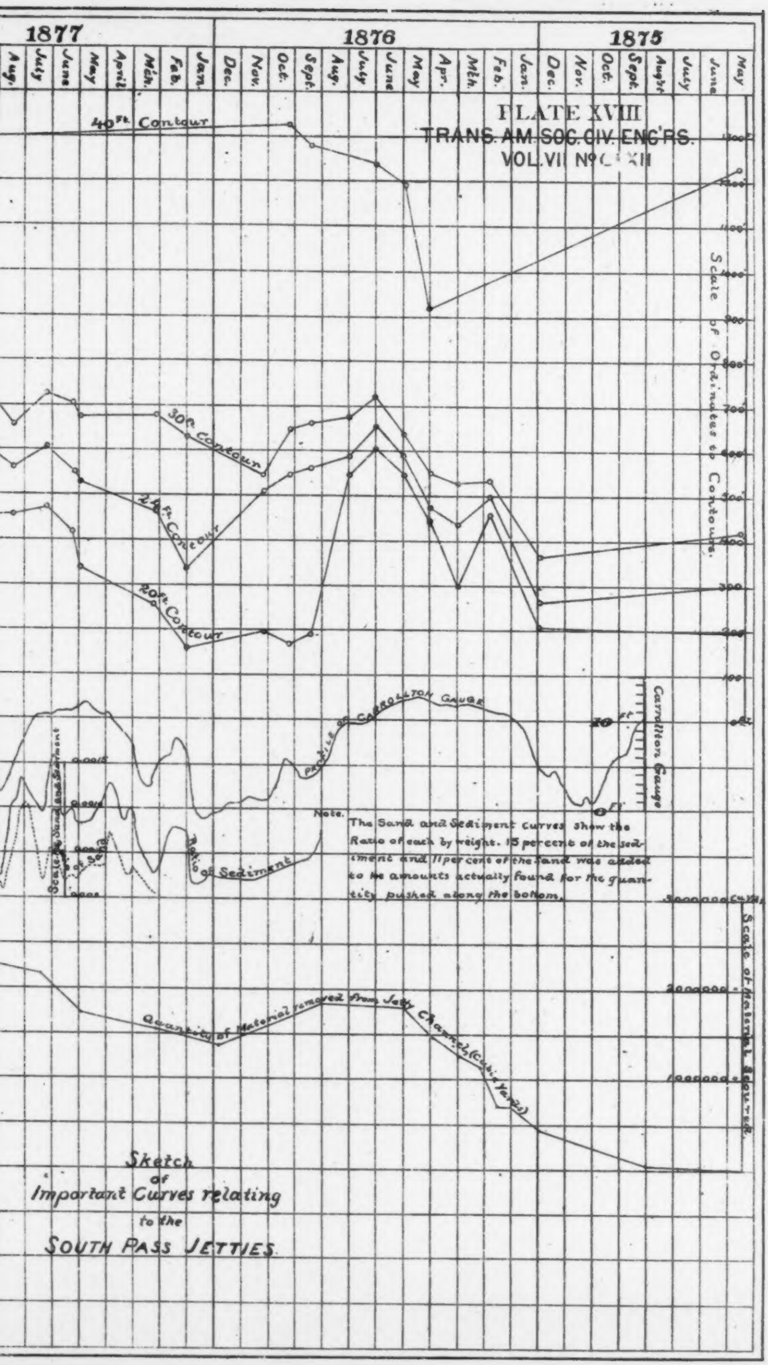
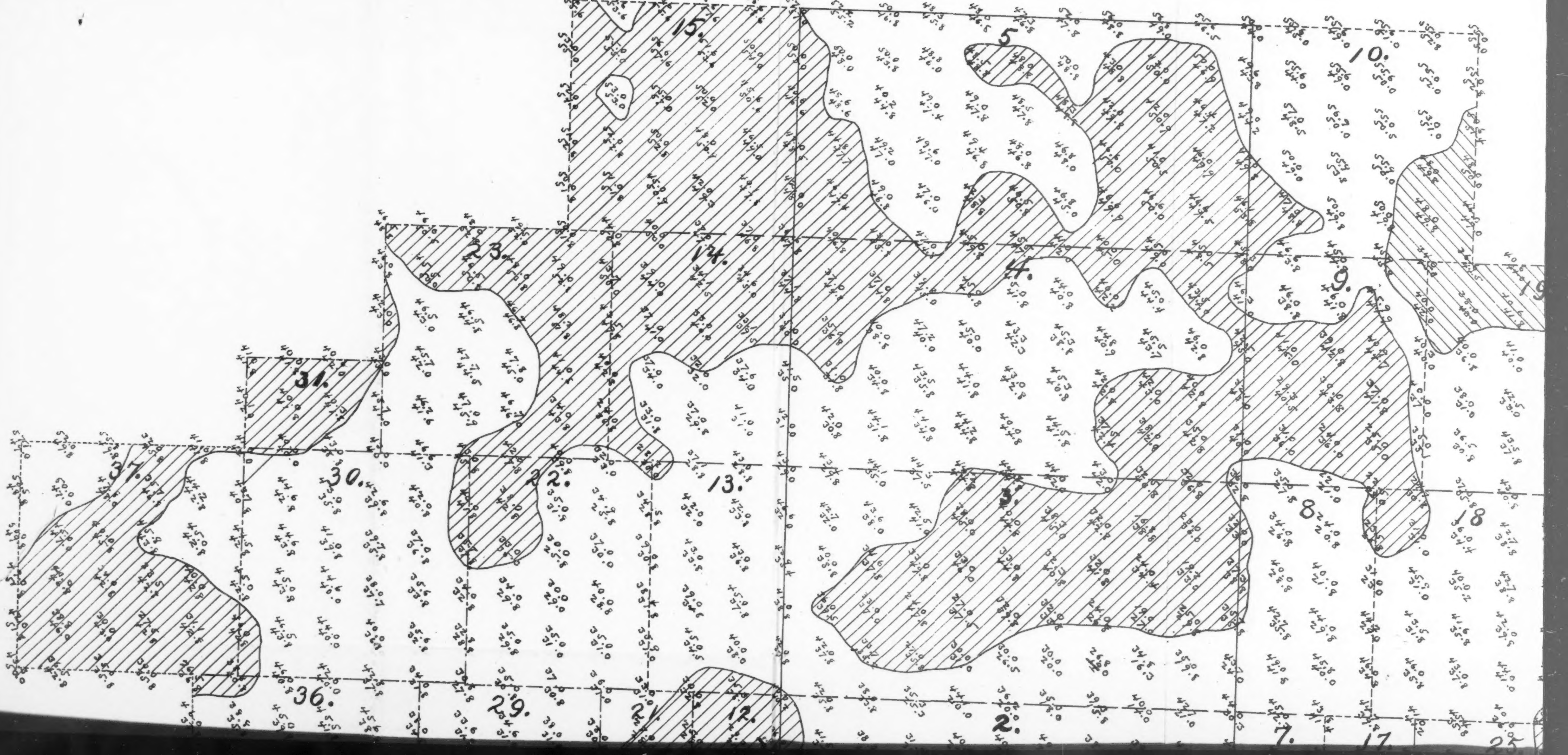
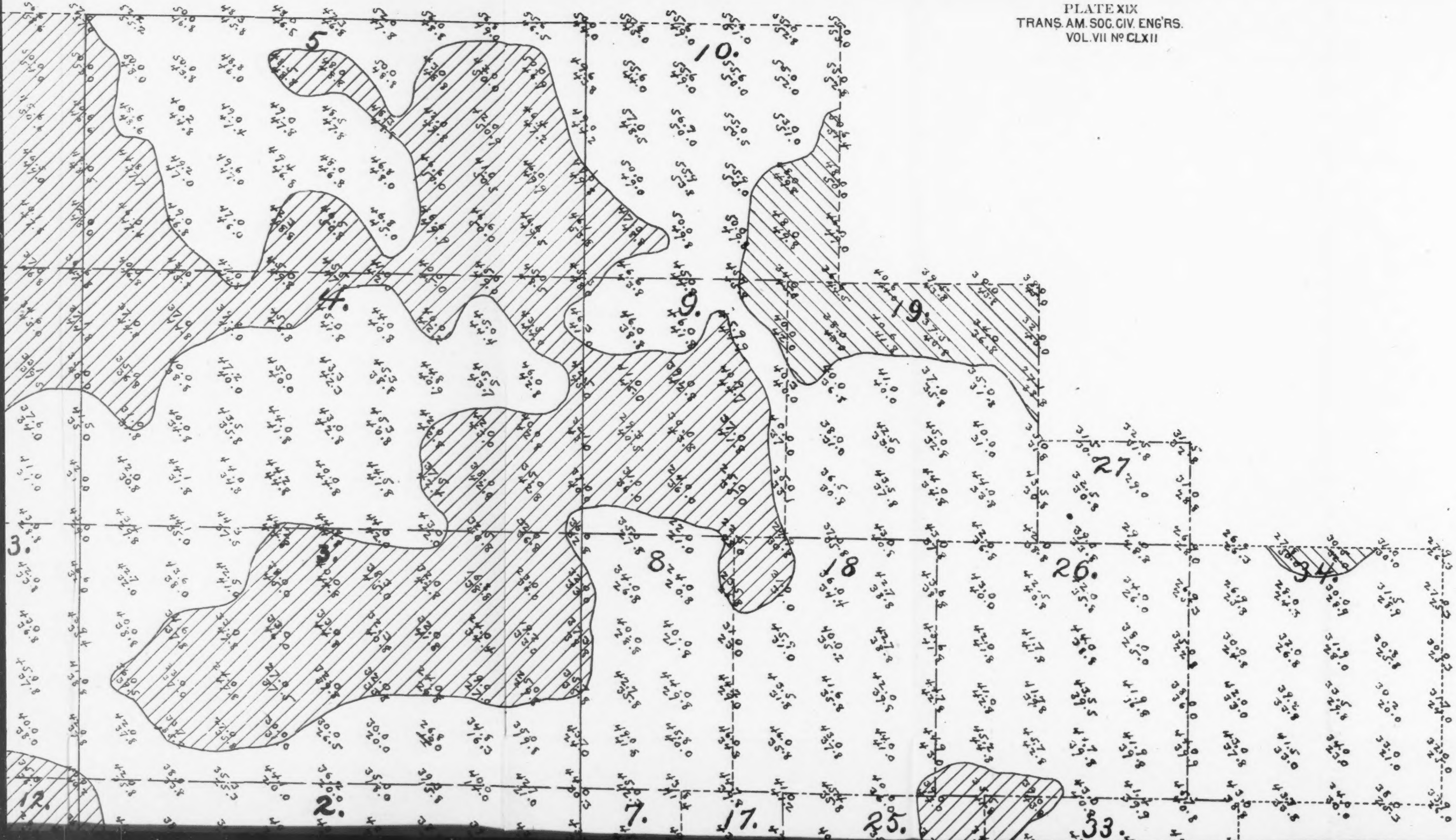


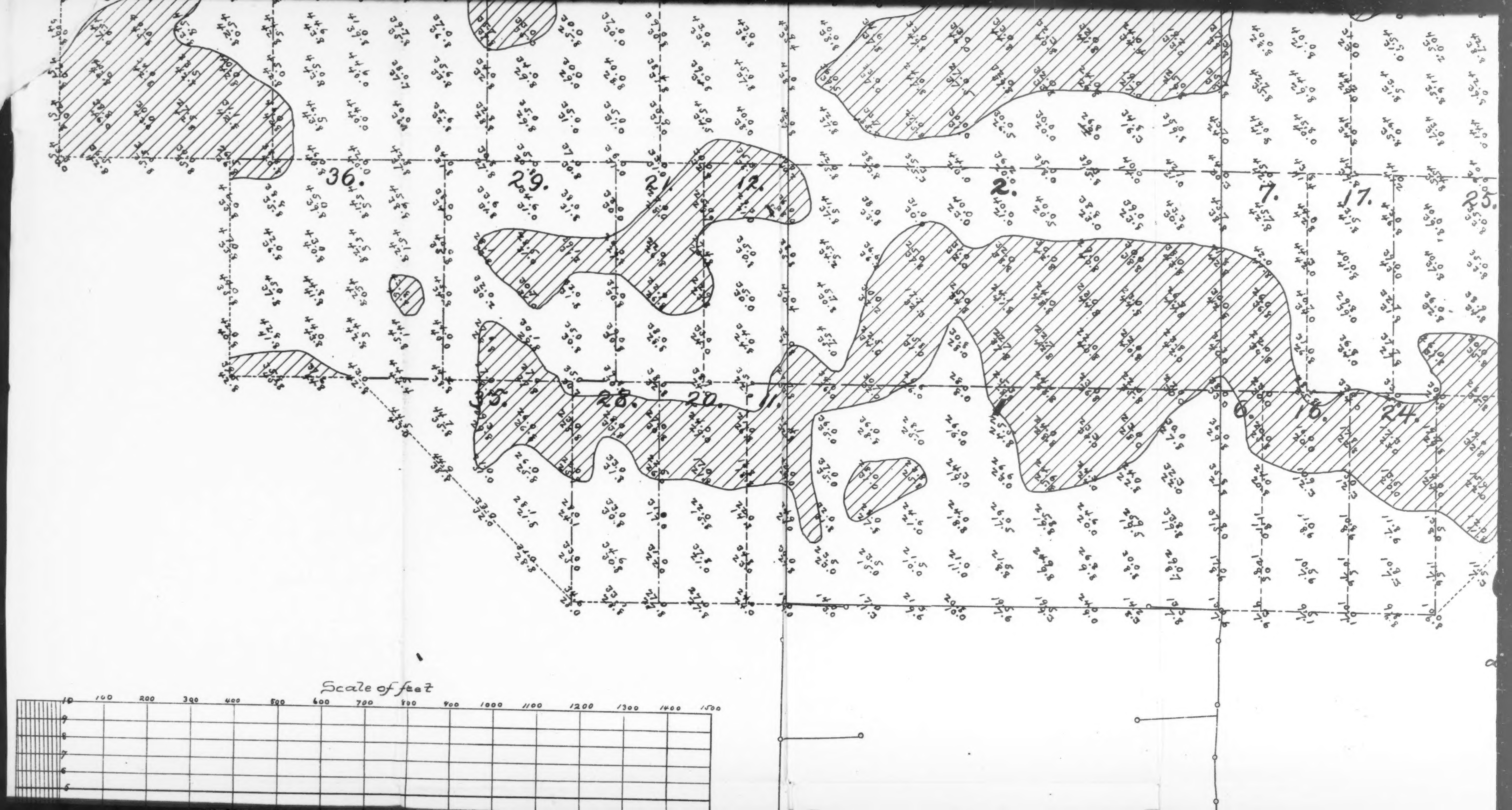
PLATE XVIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No. CLXII
1877
1876
1875
Aug.
July
June
May
April
Mch.
Feb.
Jan.
Dec.
Nov.
Oct.
Sept.
Aug.
July
June
May
Apr.
Mch.
Feb.
Jan.
Dec.
Nov.
Oct.
Sept.
Augst.
July
June
May
40 Ft. Contour
30 Ft. Contour
24 Ft. Contour
20 Ft. Contour
Scale of Ordinates to Contours.
Profile of Carrollton Gauge
Carrollton Gauge
10 Ft.
0 Ft.
Ratio of Sediment
Scale for Sand and Sediment
Note. The Sand and Sediment Curves show the Ratio of each by weight. 15 percent of the sediment and 11 percent of the sand was added to the amounts actually found for the quantity pushed along the bottom.
Quantity of Material removed from Jetty Channel (Cubic Yards)
Scale of Material Scoured.
3000000 Cu. Yd.
2000000
1000000
Sketch of Important Curves relating to the South Pass Jetties

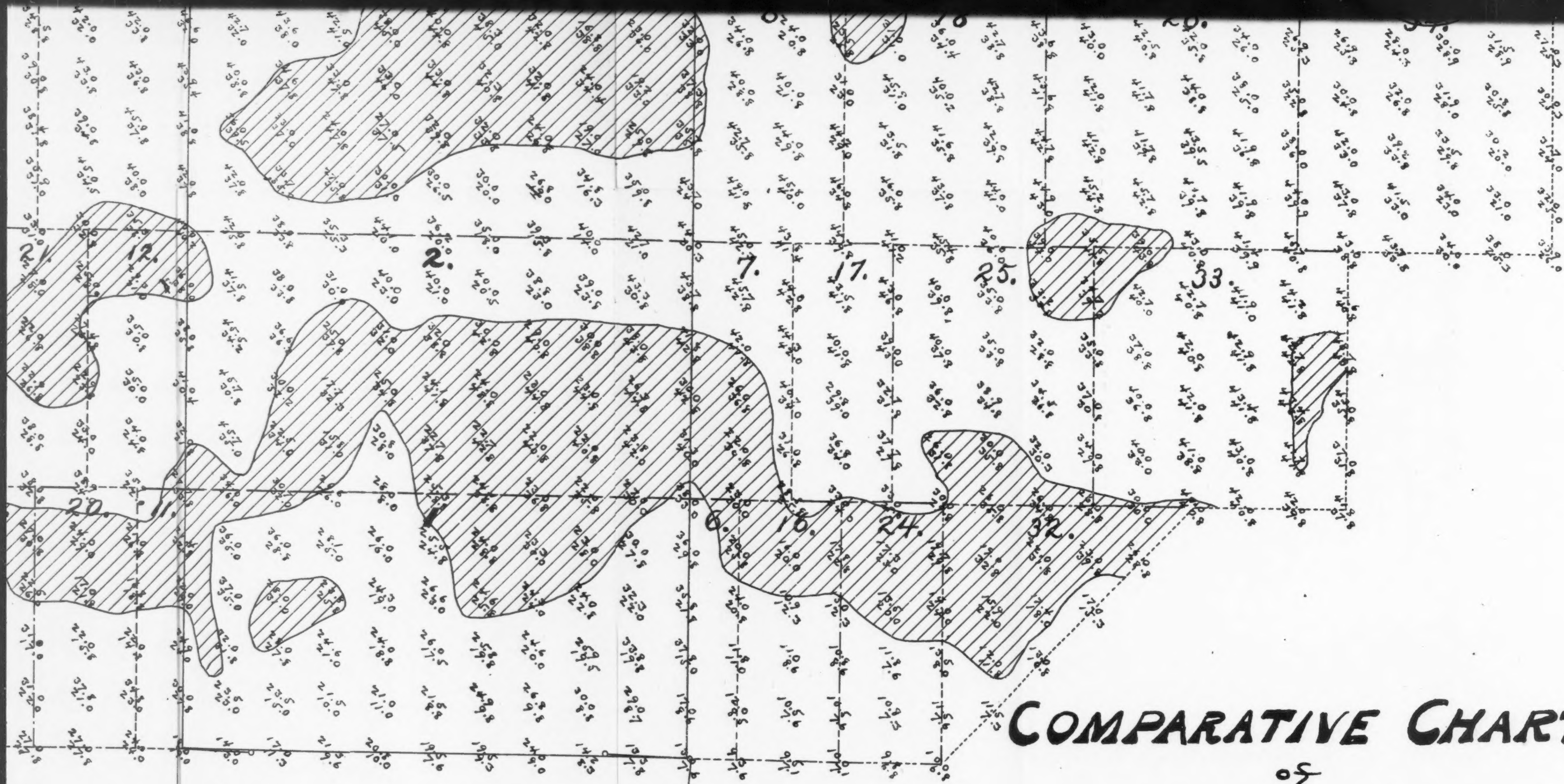


15.
5
10.
23.
14.
4.
9.
19
31.
37.
30.
22.
13.
3.
8
18
36.
29.
21.
12.
2.
7.
17
25

PLATE XIX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII No CLXII




36.
29.
21.
12.
2.
7.
17.
25.
35.
28.
20.
11.
1.
6.
16.
24.
Scale of feet
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500



COMPARATIVE CHART

of

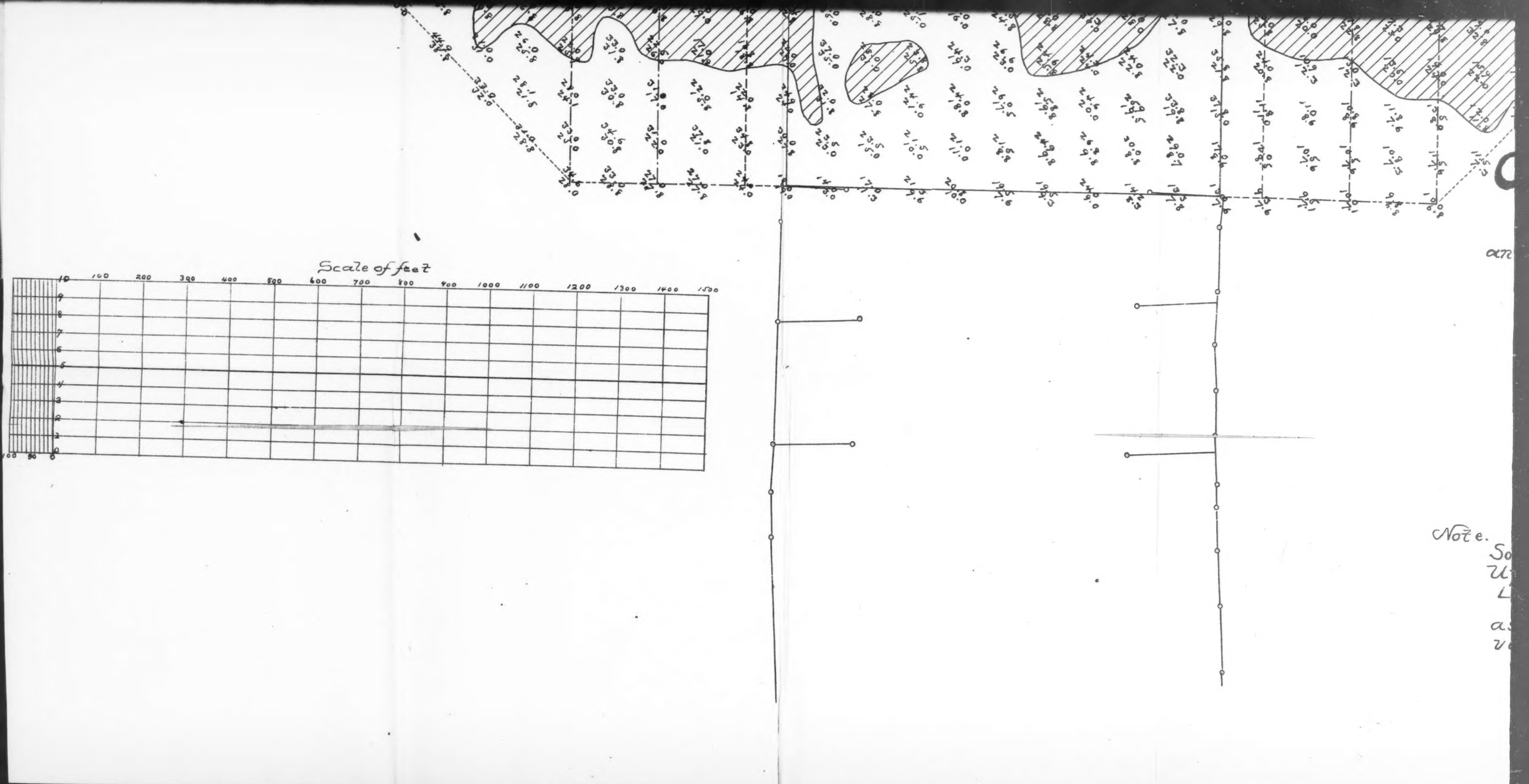
an Area of about 0.278 Sq. miles or 178.37 Acres

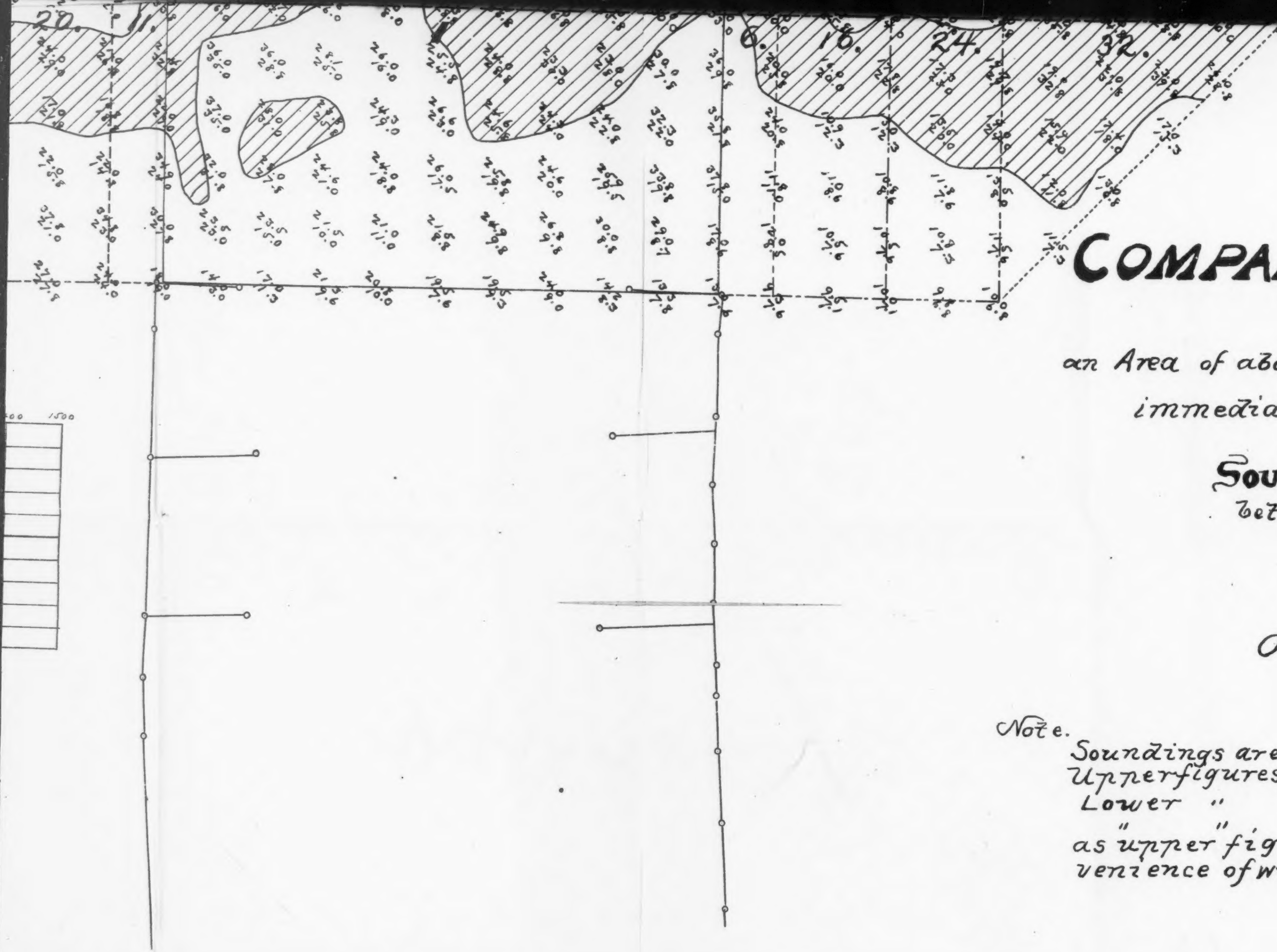
immediately seaward of the end

of the

SOUTH-PASS JETTIES

between the dates


Scale of feet
100 50 0
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
0 1 2 3 4 5 6 7 8 9 10
an
Note.



COMPARATIVE CHART

of

an Area of about 0.278 Sq. miles or 178.37 Acres

immediately Seaward of the end

of the

SOUTH-PASS JETTIES

between the dates

of

May - 1875

and

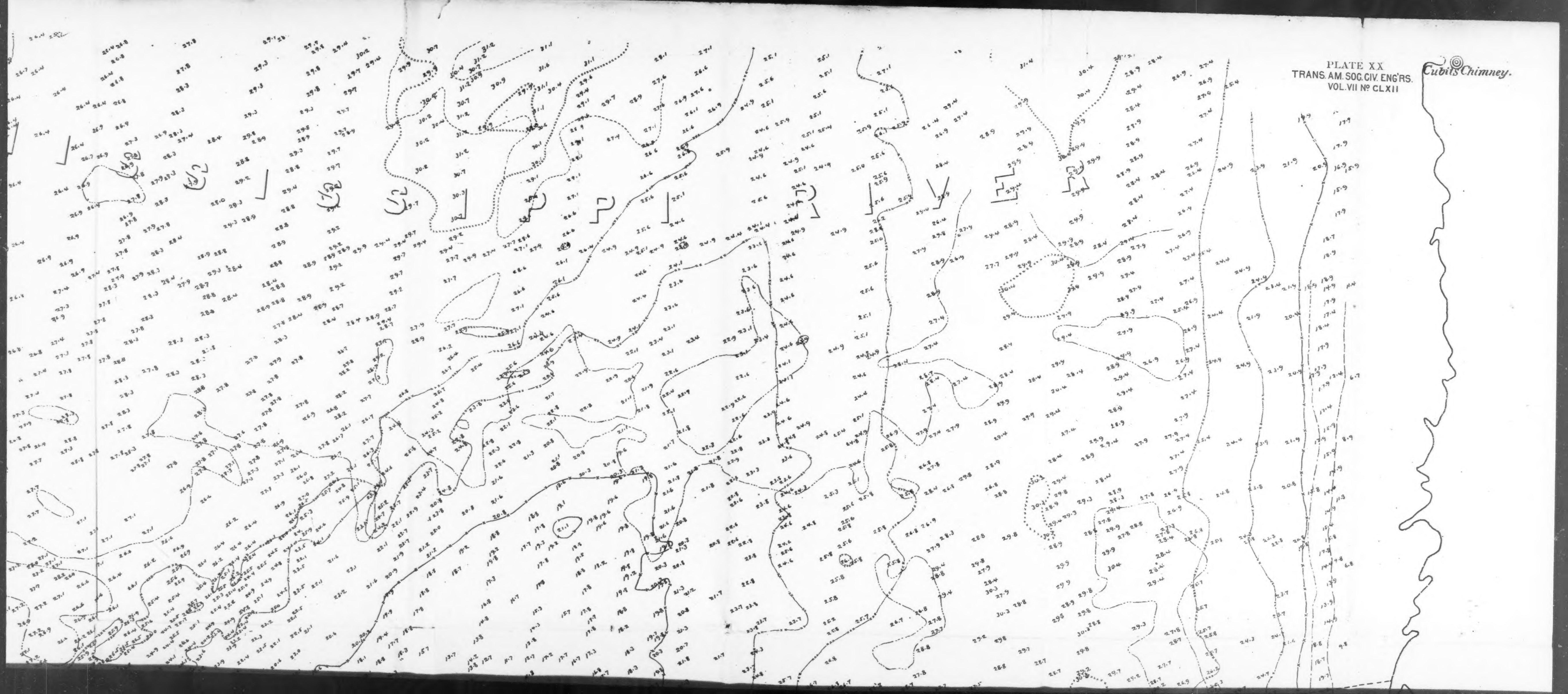
Oct. 20th - 23rd, 1877.

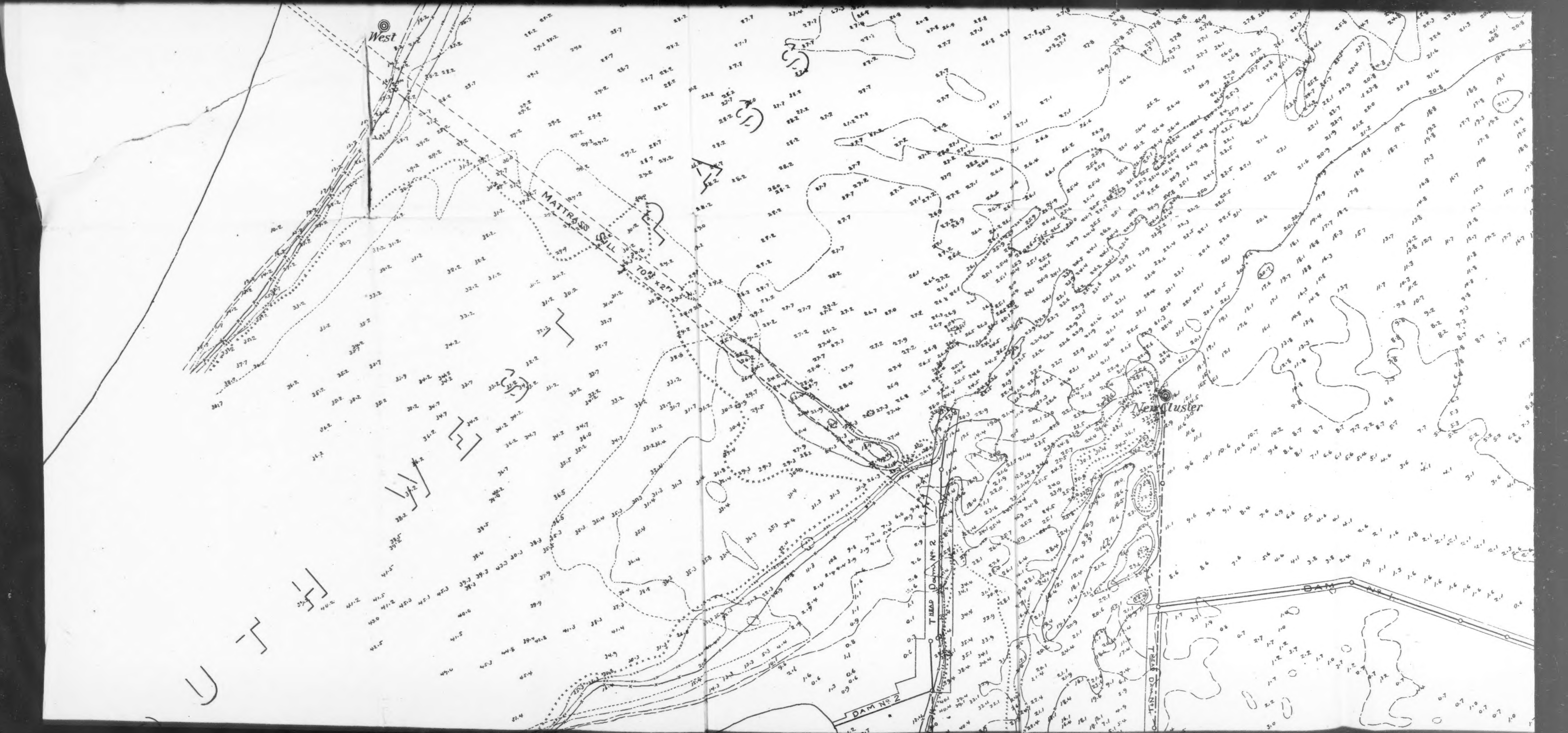
Note.

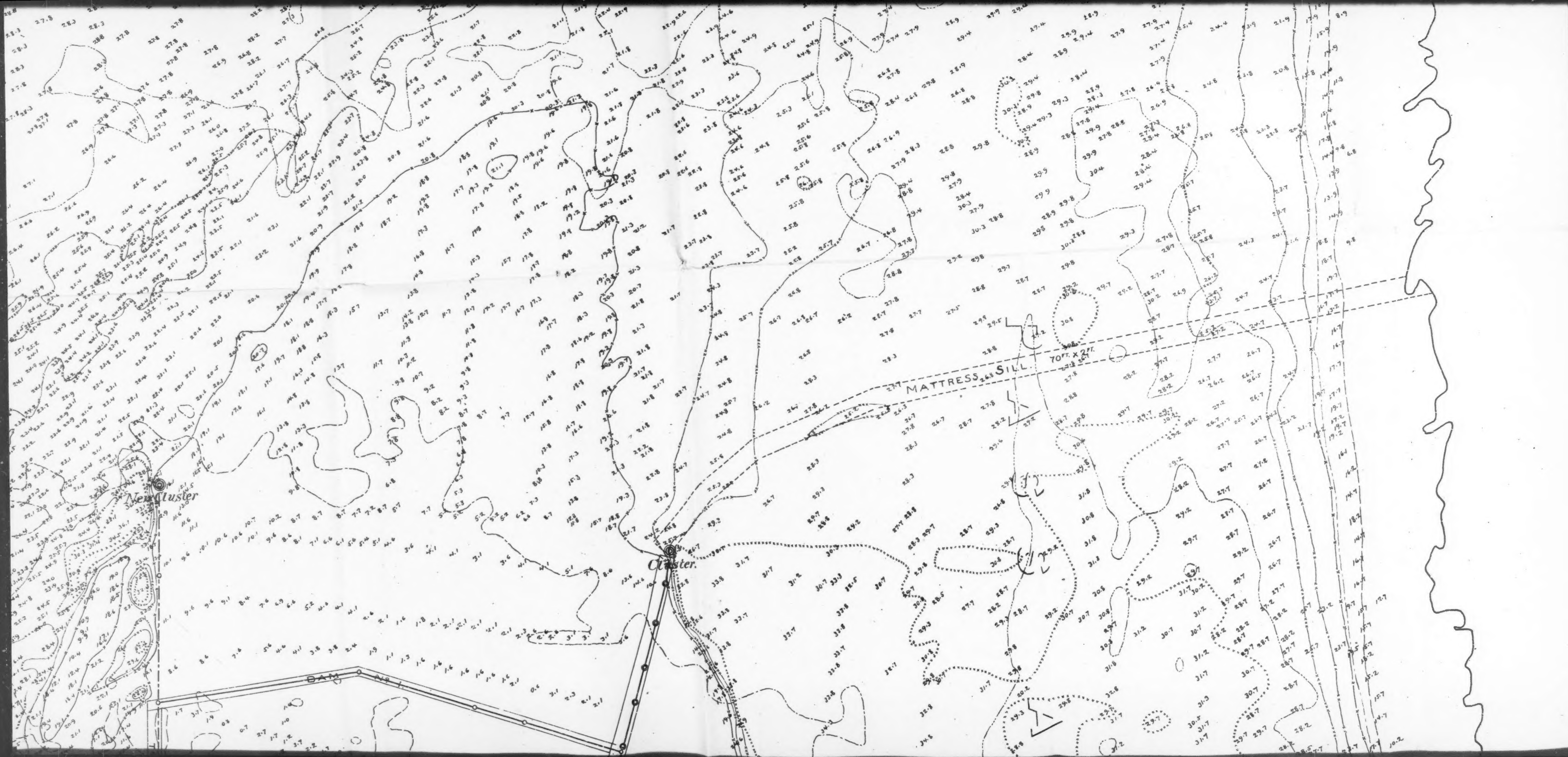
Soundings are expressed in feet and tenths of a ft.
Upper figures denote depth in Oct. 1877.
Lower " " " " May 1875.
" " should occupy the same place as upper figures—they are displaced for convenience of writing. Areas shaded denote Shoaling—
Blank Areas " " Scour—


Telegraph
Upper West
Midwest
West
MATTRASS

PLATE XX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VII № CLXII




West
MATTRASS SILL 70' x 2'
New Cluster
T HEAD DAM No 2
DAM No 2
DAM No 1



New Custer
Custer.
MATTRESS SILL.
70FT. x 2FT.
DAM No 1

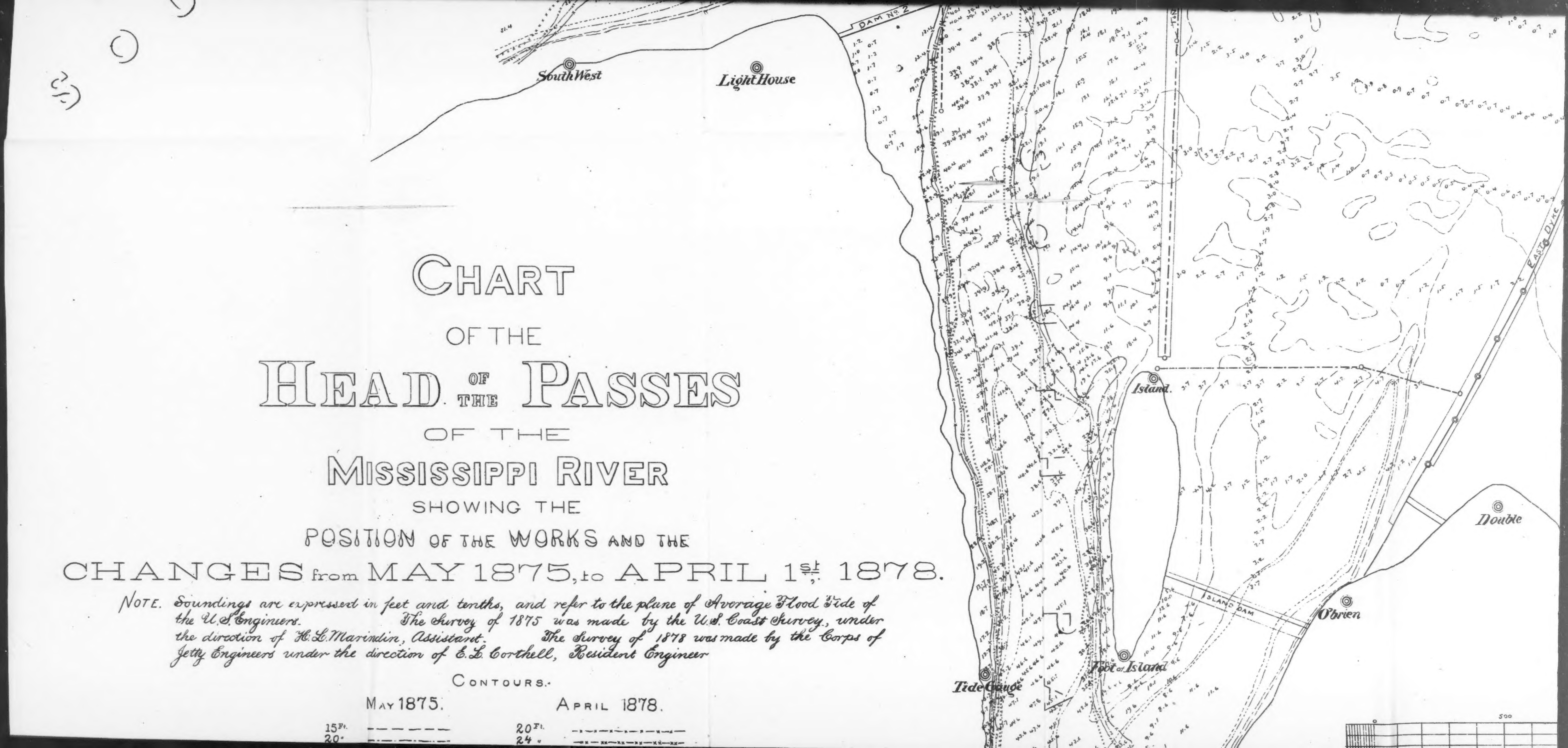


CHART
OF THE
HEAD OF THE PASSES
OF THE
MISSISSIPPI RIVER
SHOWING THE
POSITION OF THE WORKS AND THE
CHANGES from MAY 1875, to APRIL 1st, 1878.
NOTE. Soundings are expressed in feet and tenths, and refer to the plane of Average Flood Tide of the U.S. Engineers. The Survey of 1875 was made by the U.S. Coast Survey, under the direction of H.L. Marindin, Assistant. The Survey of 1878 was made by the Corps of Jetty Engineers under the direction of E.L. Corthell, Resident Engineer
CONTOURS.-
MAY 1875.
APRIL 1878.
15 Ft.
20 Ft.
20
24
DAM No 2
South West
Light House
Island.
Foot of Island
Tide Gauge
ISLAND DAM
O'brien
Double
EAST DYKE
0
500

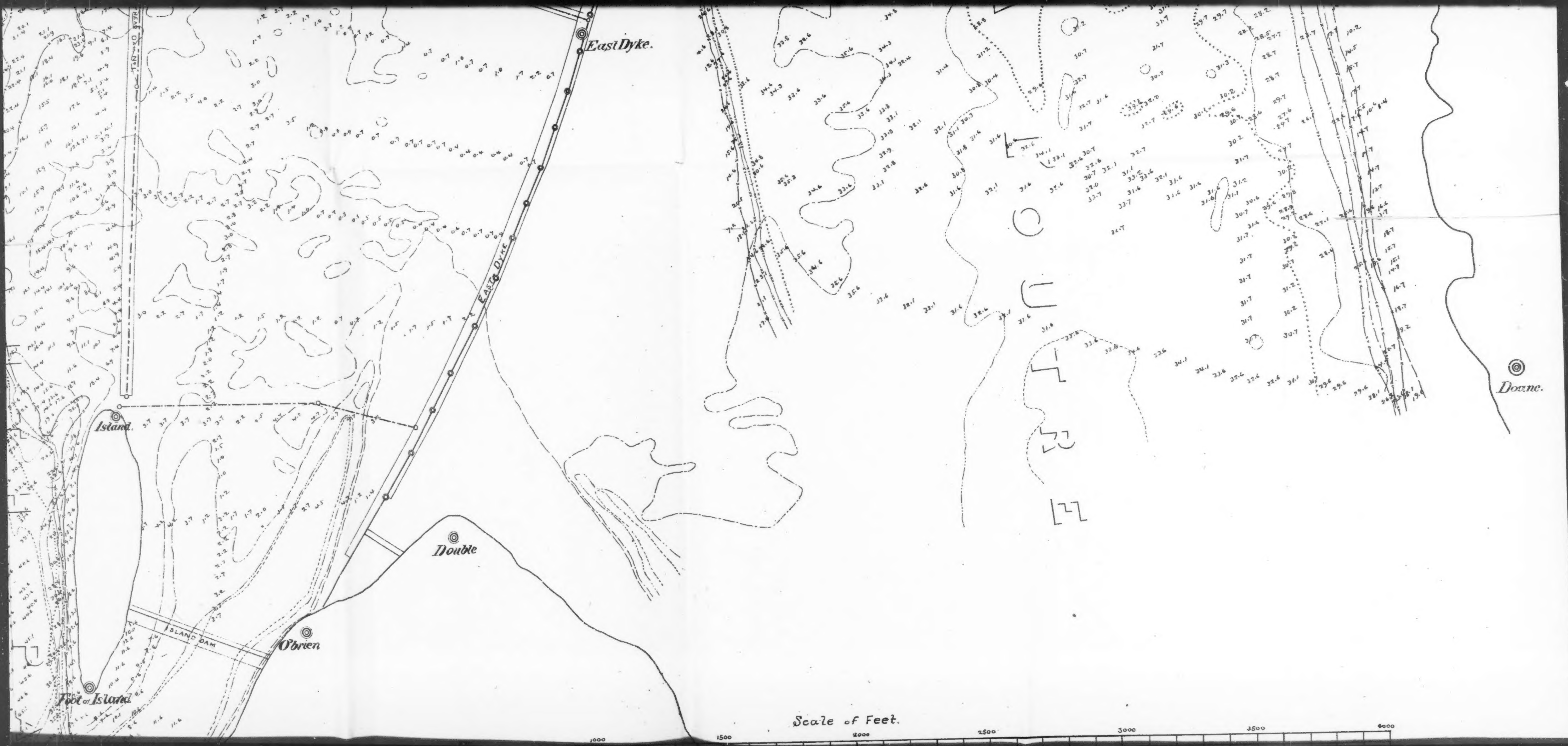
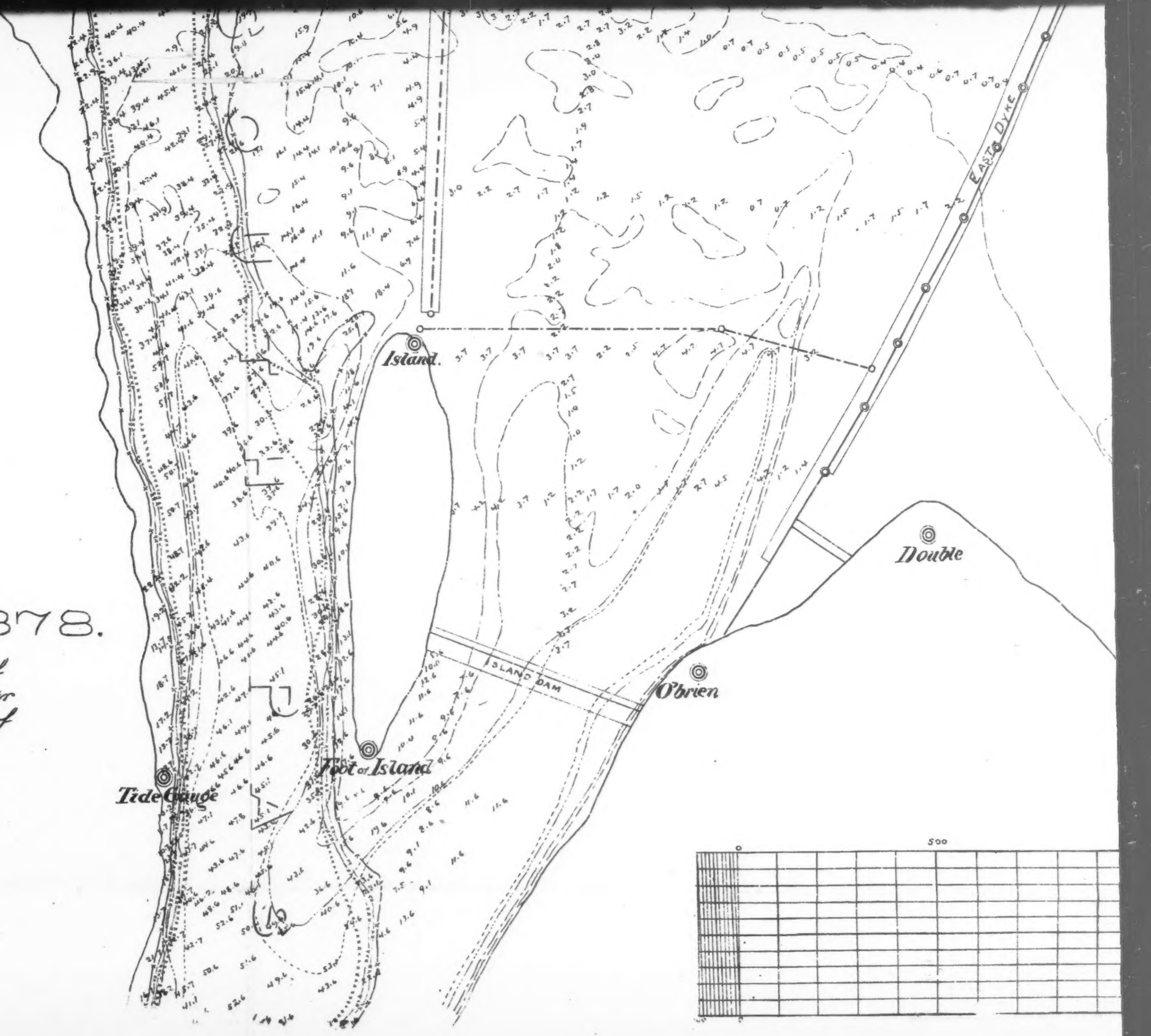

East Dyke.
EAST DYKE
Island.
ISLAND DAM
Double
O'brien
Foot of Island
Doane.
Scale of Feet.
1000
1500
2000
2500
3000
3500
4000

CHART OF THE HEAD OF THE PASSES OF THE MISSISSIPPI RIVER SHOWING THE POSITION OF THE WORKS AND THE CHANGES from MAY 1875, to APRIL 1st. 1878.

NOTE. Soundings are expressed in feet and tenths, and refer to the plane of Average Flood Tide of the U.S. Engineers. The Survey of 1875 was made by the U.S. Coast Survey, under the direction of H.L. Marindin, Assistant. The Survey of 1878 was made by the Corps of Jetty Engineers under the direction of E.L. Corthell, Resident Engineer

CONTOURS.

MAY 1875.	APRIL 1878.
15 Ft.	20 Ft.
20 "	24 "
26 "	26
30 "	30 "



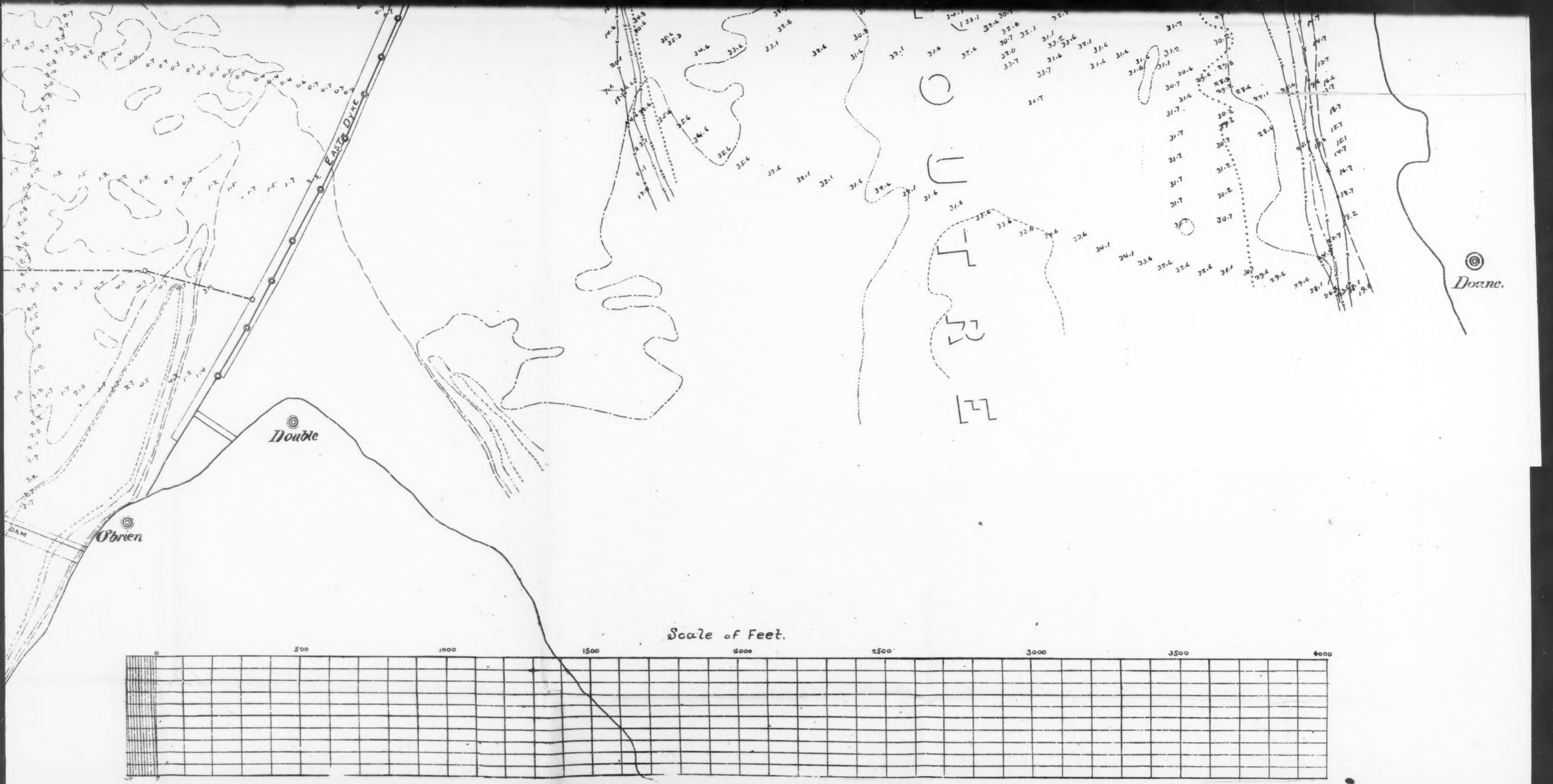
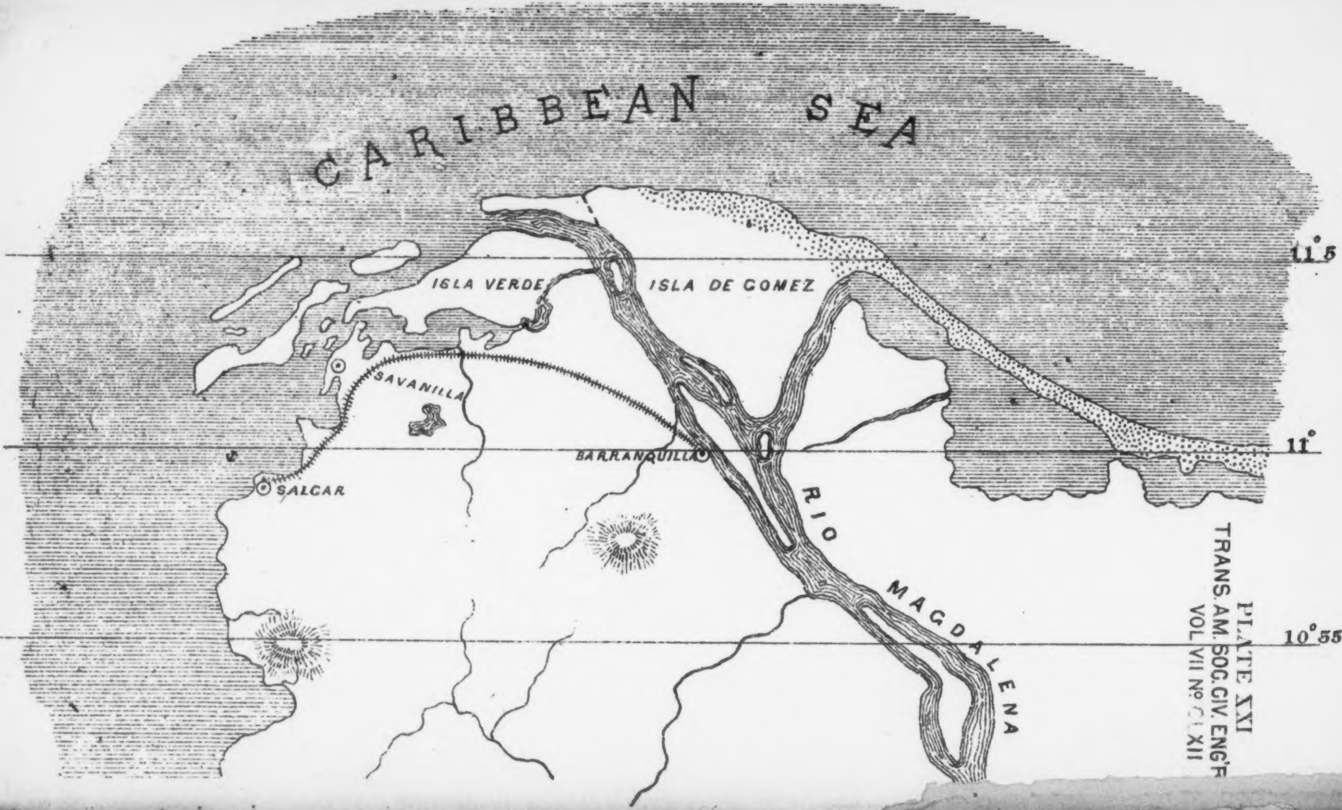
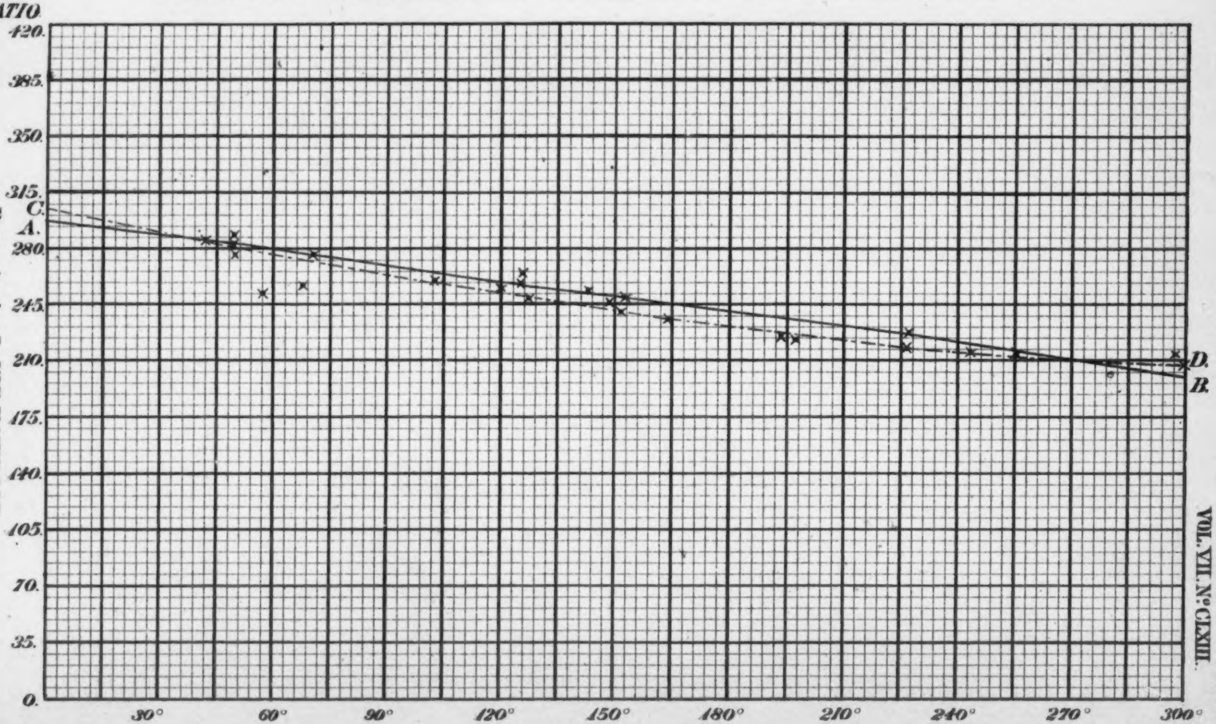

EAST DYKE
Double
O'brien
DAM
Doane.
Scale of Feet.
0
500
1000
1500
2000
2500
3000
3500
4000

PLATE XXI
TRANS. AM. SOC. CIV. ENG'R
VOL VII No CLXII



THURSTON. RELATION OF TENSILE TO TORSIONAL RESIST

THURSTON—RELATION OF TENSILE TO TORSIONAL RESISTANCE.



Determinations by W. R. BAIRD, M.E.

PLATE XXII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXIII.

PLATE XXIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXIV.

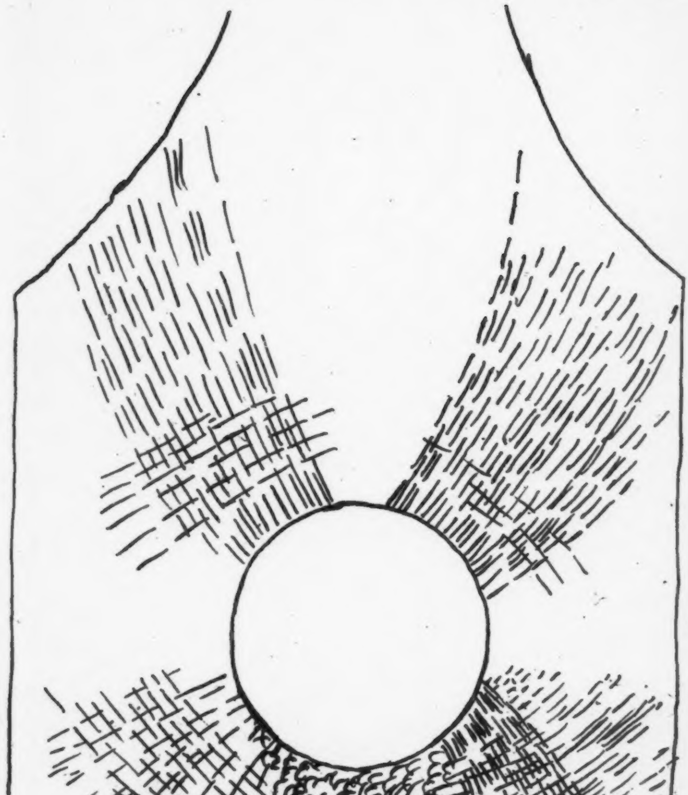


Fig. 1.

PLATE XXIV
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. N° CLXIV.

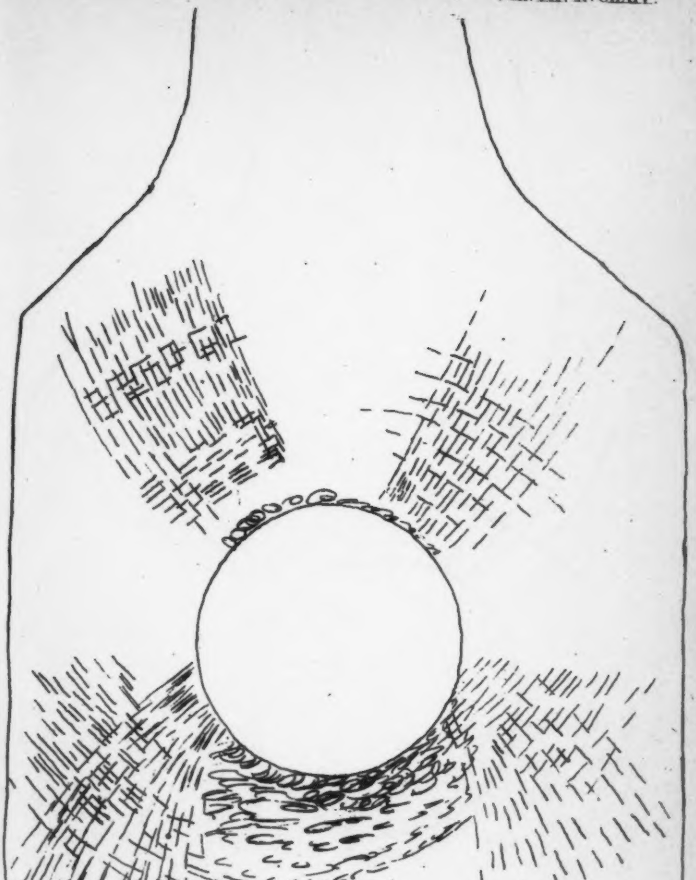


Fig. 2.

PLATE XXV
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXIV.

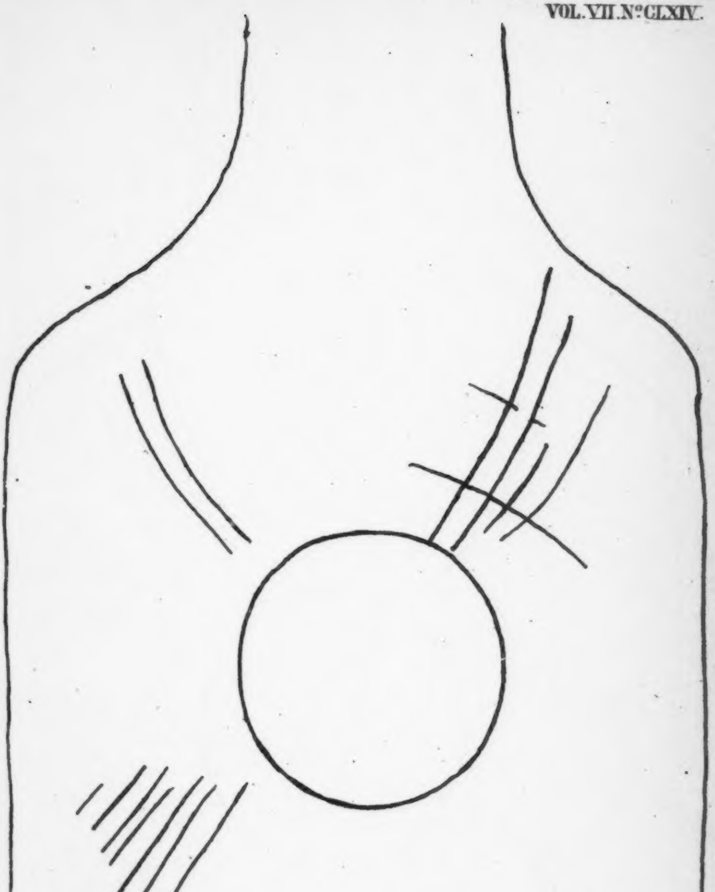


Fig. 3.

PLATE XXVI
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. N° CLXIV.

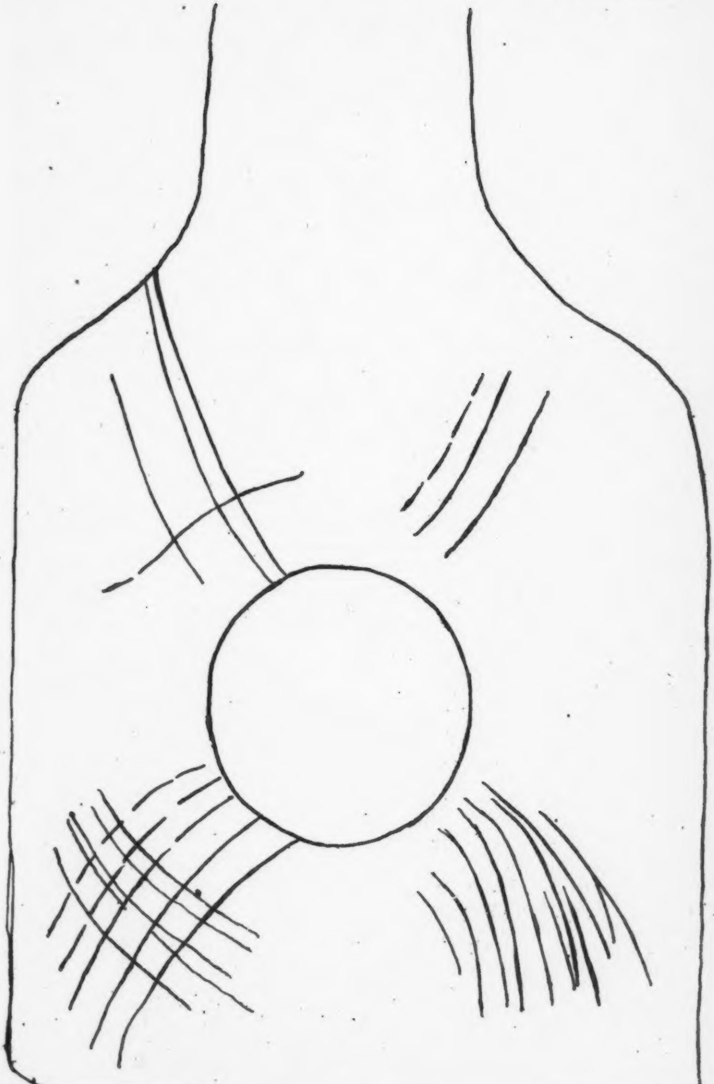


Fig. 4.

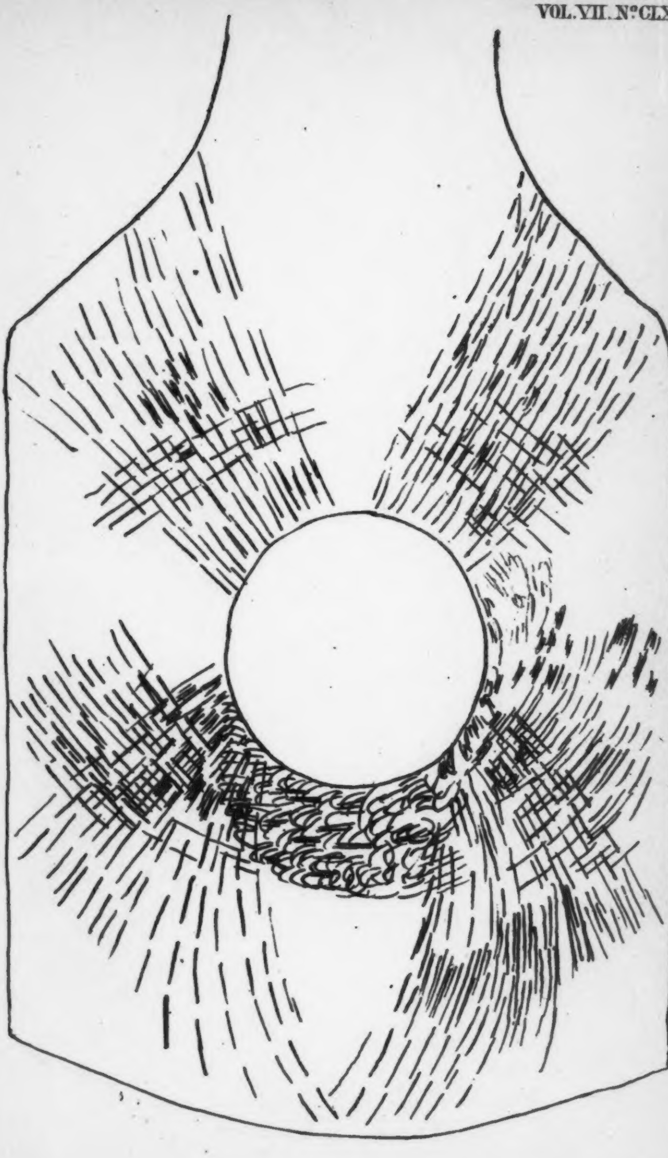


Fig. 5.

PLATE XXVIII.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. N° CLXIV.

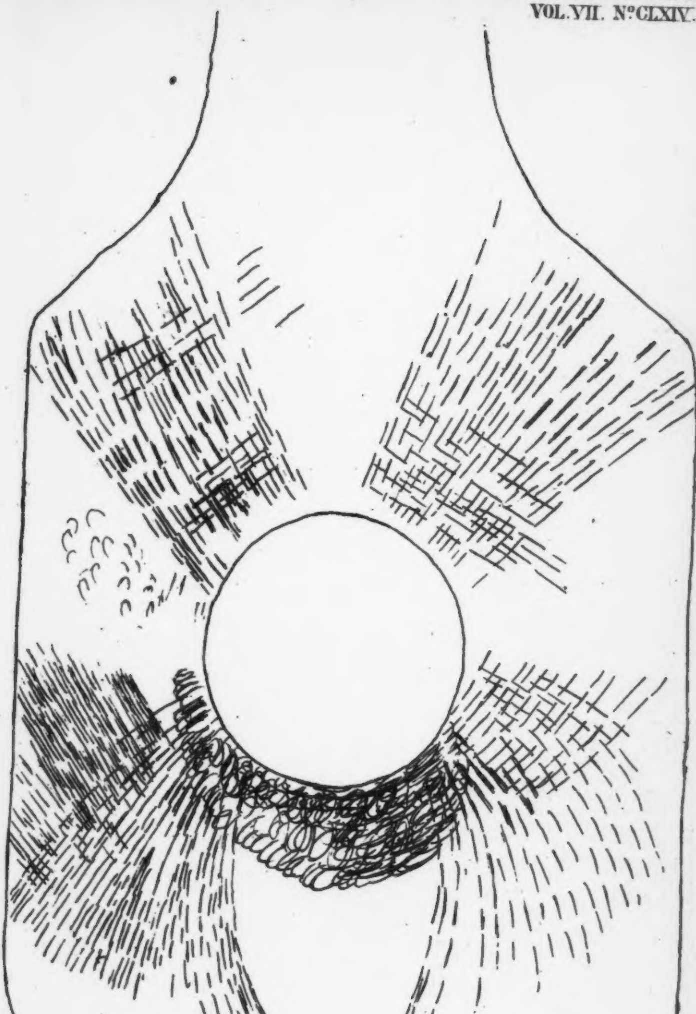


Fig. 6.

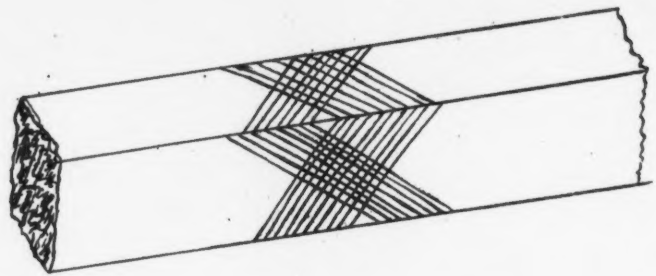


Fig. 7.

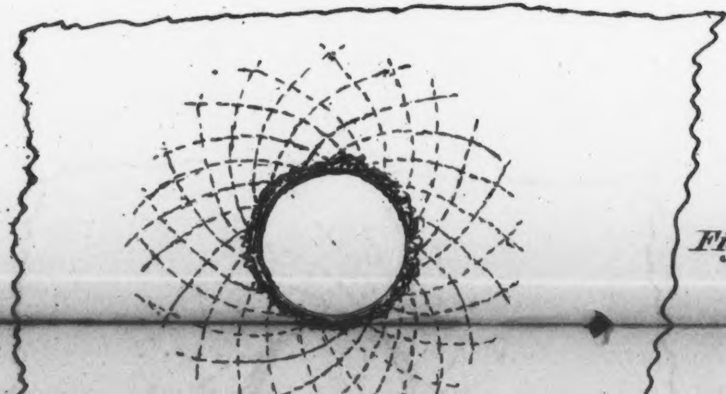


Fig. 8.

PLATE XXIX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No CLXIV.

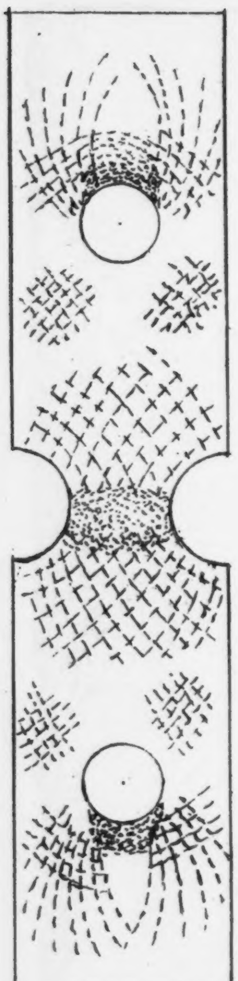


Fig. 9.

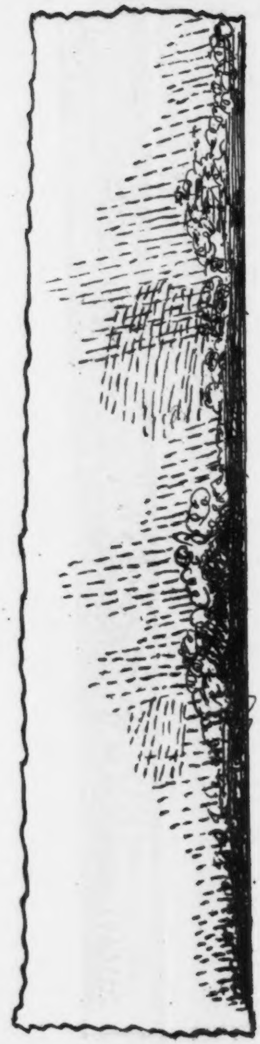


Fig. 10.

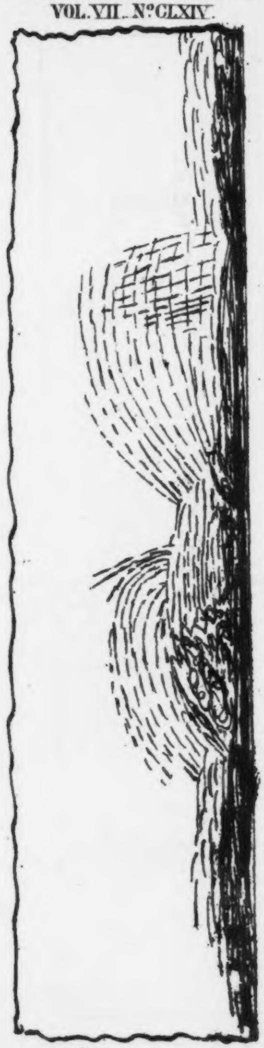
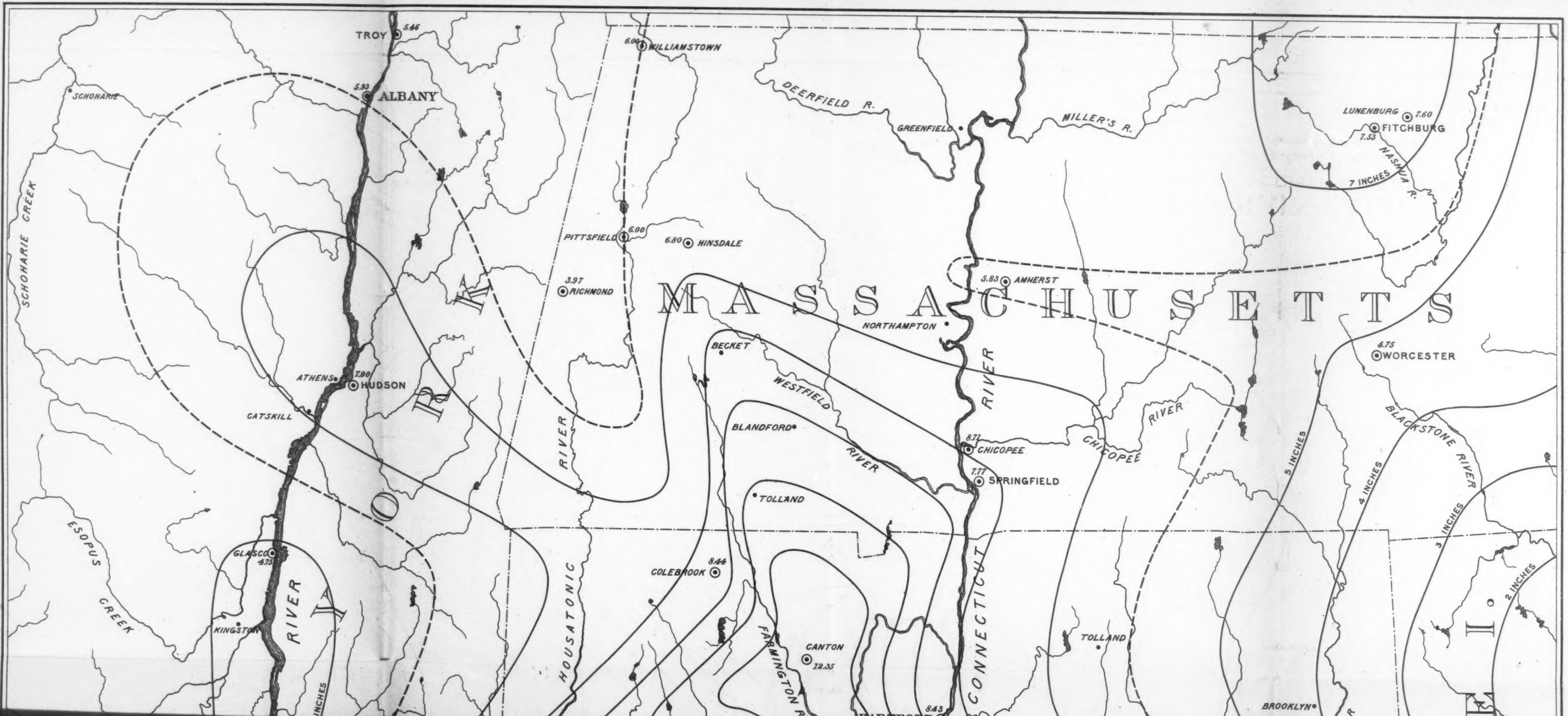


Fig. 11.



TROY 5.46
6.00 WILLIAMSTOWN
5.93 ALBANY
SCHOHARIE
DEERFIELD R.
GREENFIELD
MILLER'S R.
LUNENBURG 7.60
FITCHBURG
7.53
NASHUA R.
7 INCHES
SCHOHARIE CREEK
PITTSFIELD 6.00
6.80 HINSDALE
3.97 RICHMOND
5.83 AMHERST
MASSACHUSETTS
NORTHAMPTON
4.75 WORCESTER
BECKET
WESTFIELD
ATHENS
7.90 HUDSON
CATSKILL
BLANDFORD
RIVER
8.71 CHICOPEE
CHICOPEE
RIVER
7.77 SPRINGFIELD
5 INCHES
4 INCHES
BLACKSTONE RIVER
3 INCHES
2 INCHES
TOLLAND
ESOPUS
CREEK
GLASCO 4.75
COLEBROOK 8.44
HOUSATONIC
CONNECTICUT
KINGSTON
RIVER
FARMINGTON R.
CANTON 12.35
TOLLAND
BROOKLYN
HARTFORD 8.43
INCHES

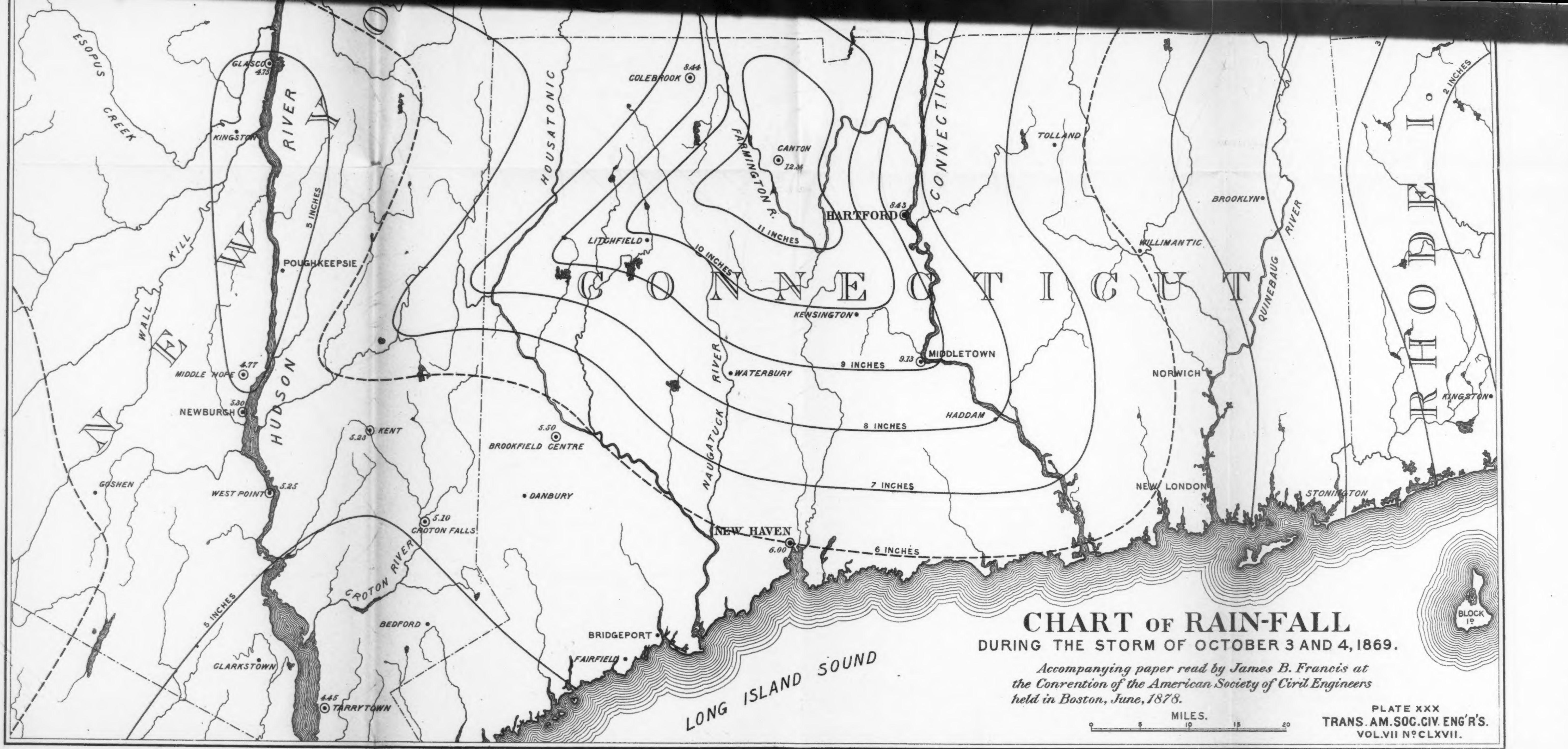


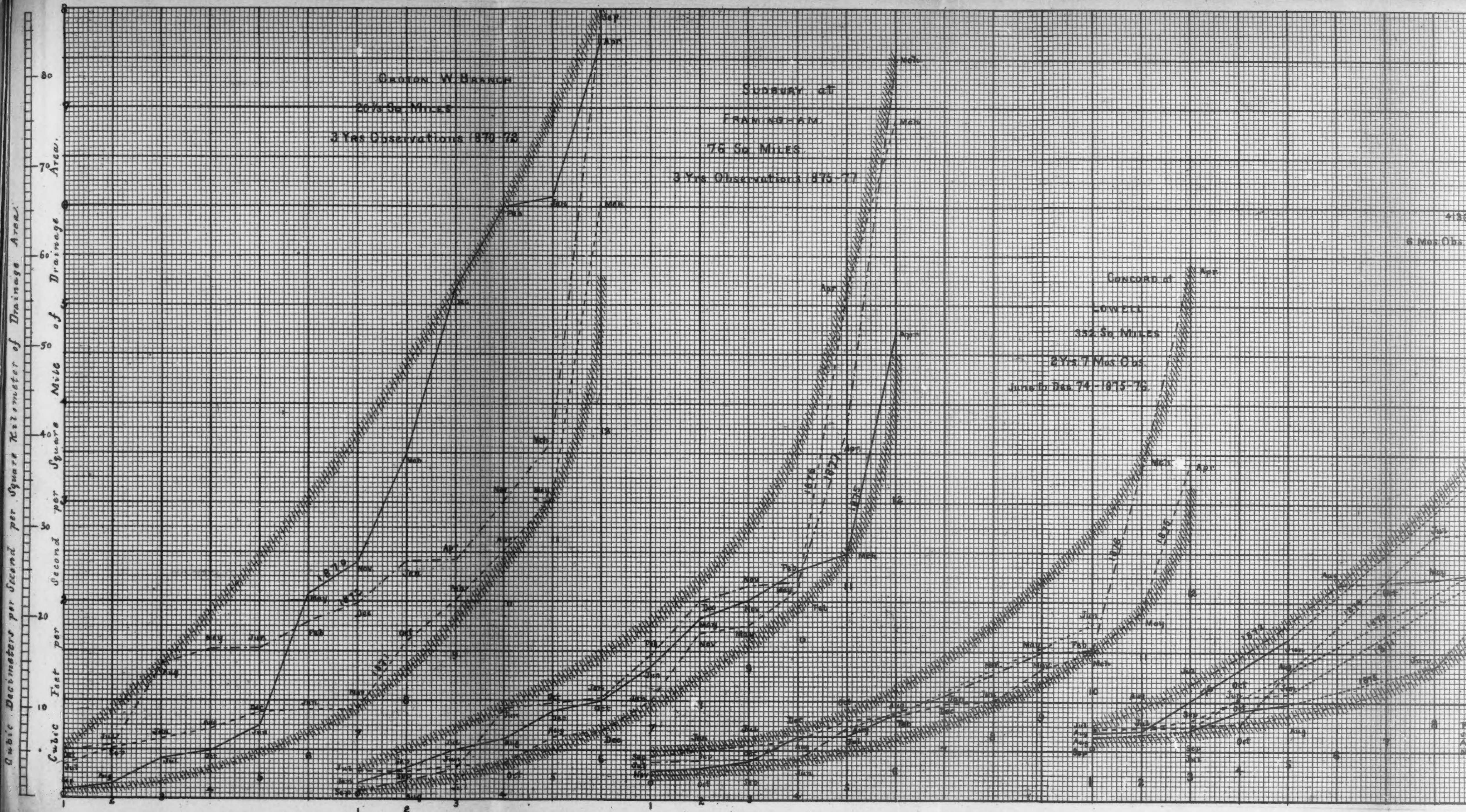
CHART of RAIN-FALL

DURING THE STORM OF OCTOBER 3 AND 4, 1869.

Accompanying paper read by James B. Francis at the Convention of the American Society of Civil Engineers held in Boston, June, 1878.

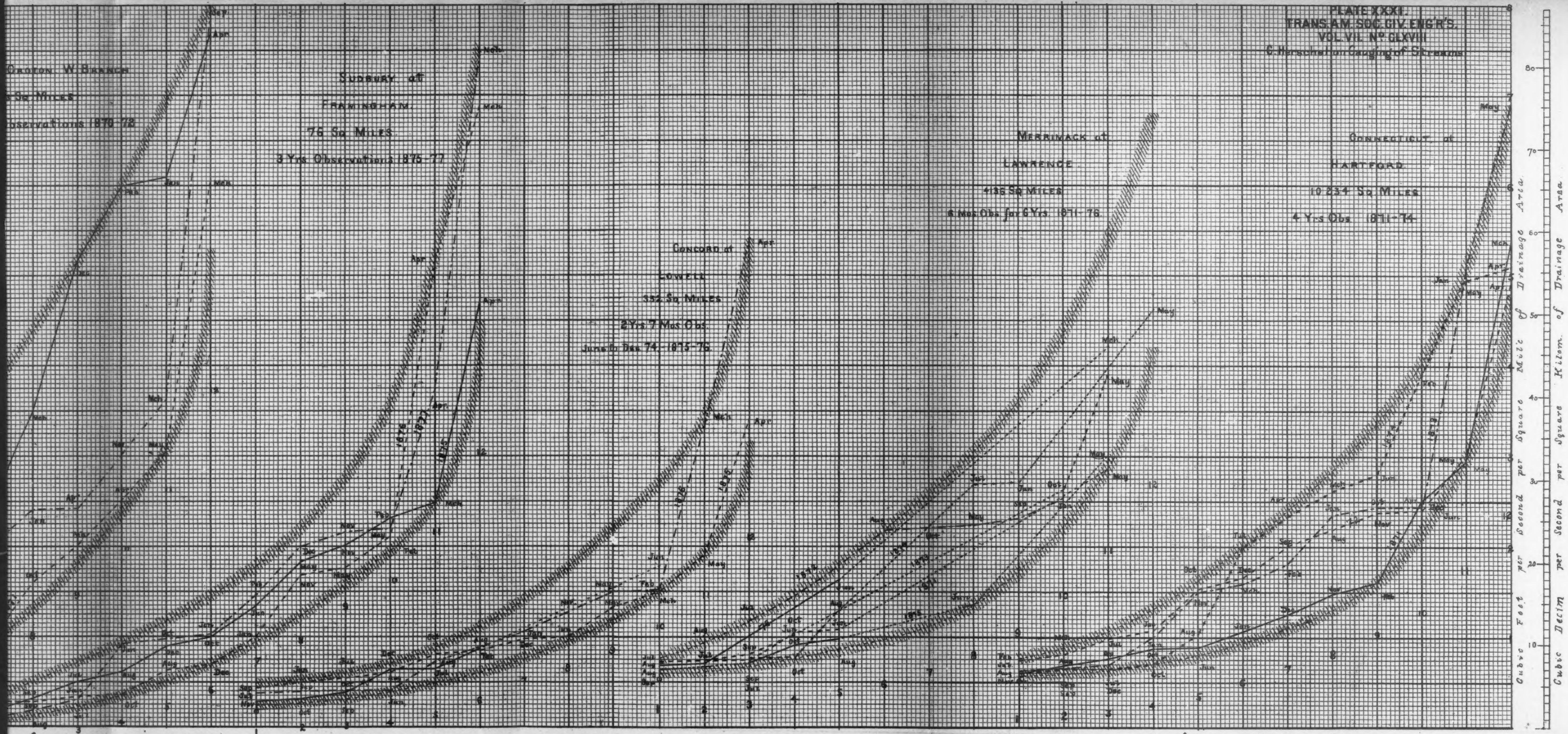
PLATE XXX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII No. CLXVII.

LITH. BY GEO. SCHLEGEL 85-87 JOHN ST. N.Y.



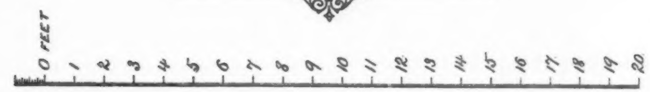
O = Dryest 6 working days.

PLATE XXXI.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No CLXVIII.
C. Herschel on Gauging of Streams.



1 cu ft per second per sq. mile = 10.933 cu decim. per sec. per sq. kilom.

BRICK ARCHES
FOR
LARGE SEWERS.



SCALE FOR FIGS. 1&2.

Fig. 1.

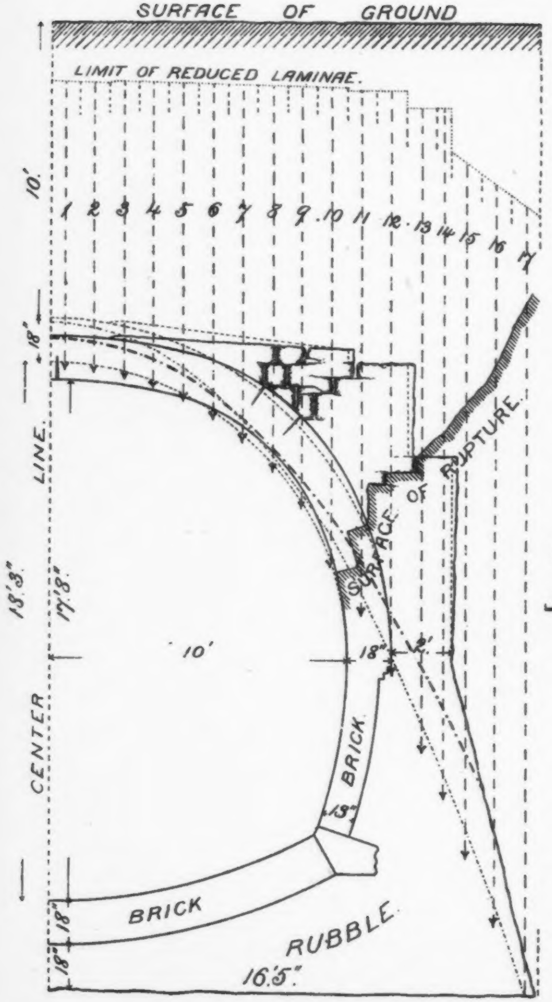
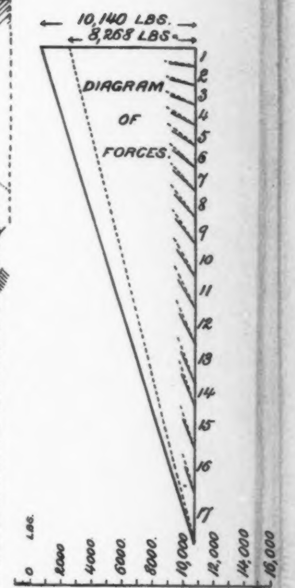


Fig. 1a.



SCALE FOR FIG.1a.

Fig. 2.

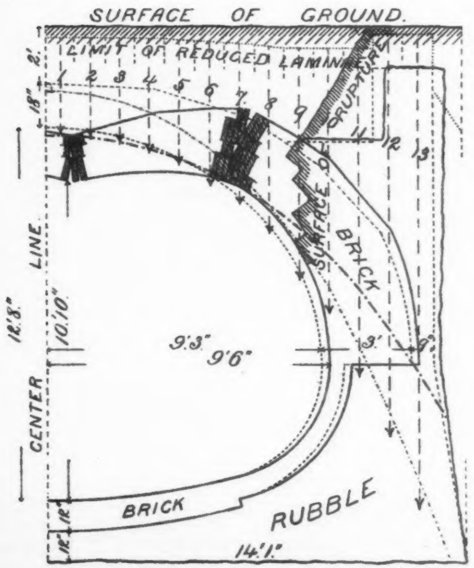
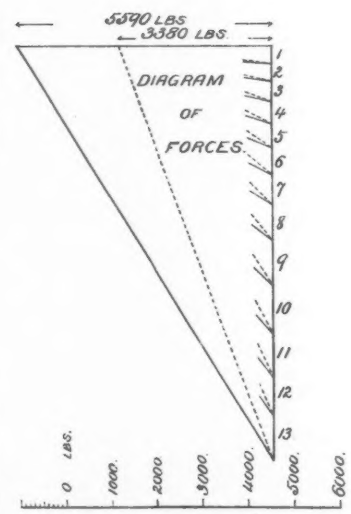
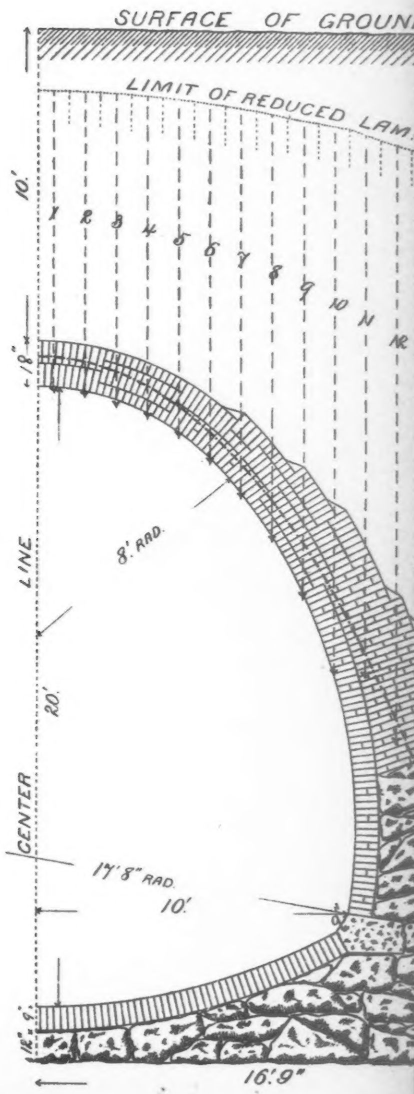


Fig. 2a.

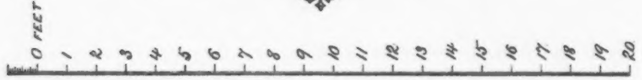


SCALE FOR FIG.2a.

Fig. 3.



BRICK ARCHES FOR LARGE SEWERS.



SCALE FOR FIGS. 1&2.

Fig. 2.

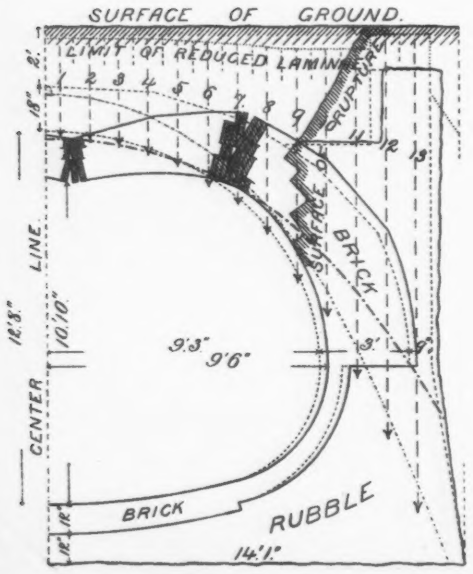
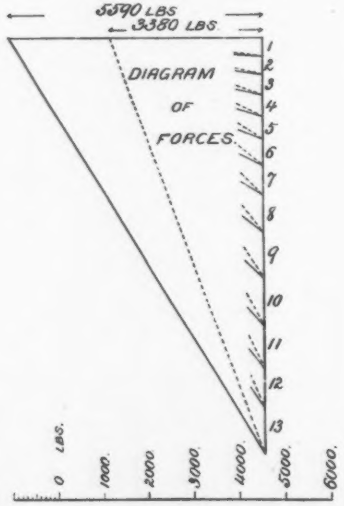


Fig. 2a.



SCALE FOR FIG. 2a.

Fig. 3.

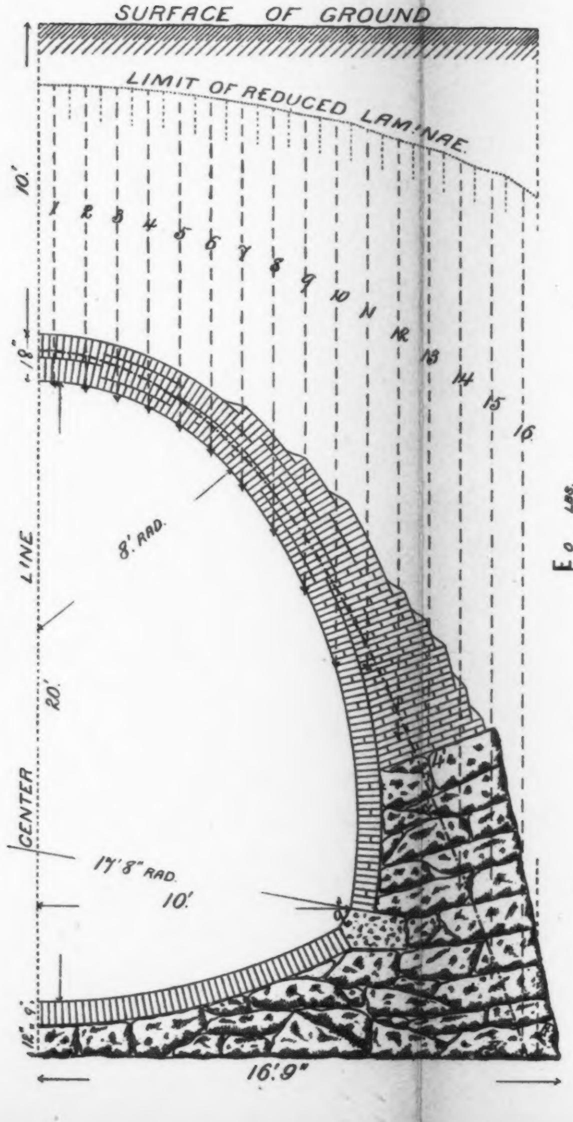
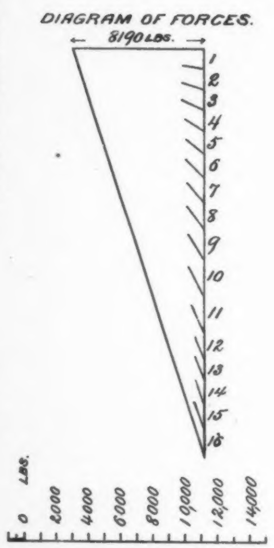
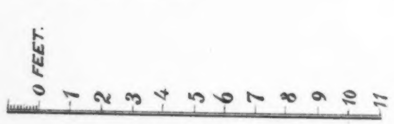


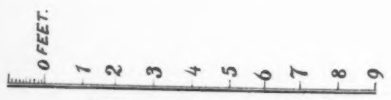
Fig. 3a.



SCALE FOR FIG. 3a.



SCALE FOR FIG. 3.



SCALE FOR FIGS. 4&5.

Fig. 5.

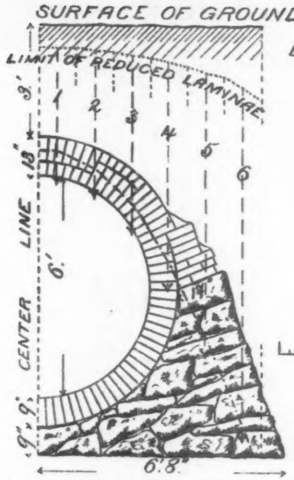
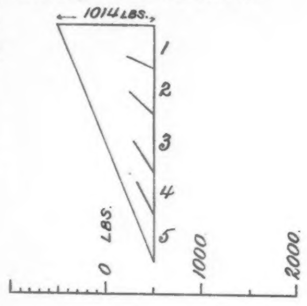


Fig. 5a.



SCALE FOR FIG. 5a.

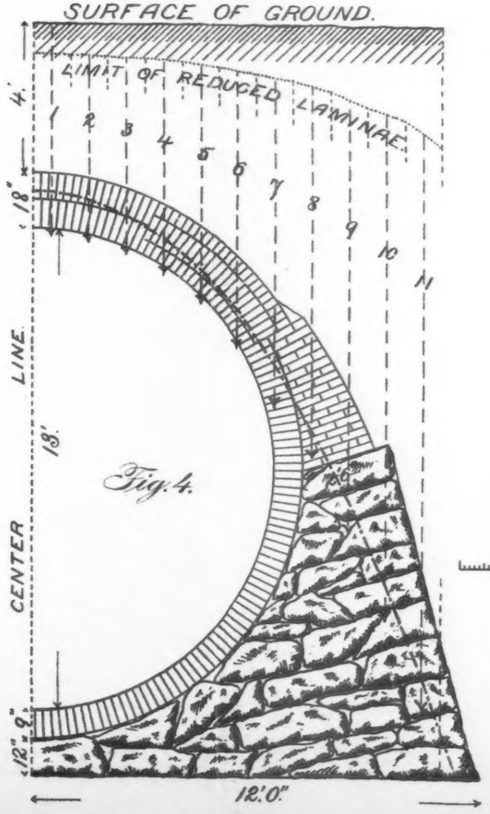
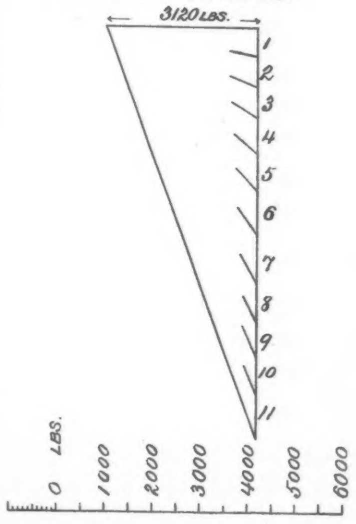


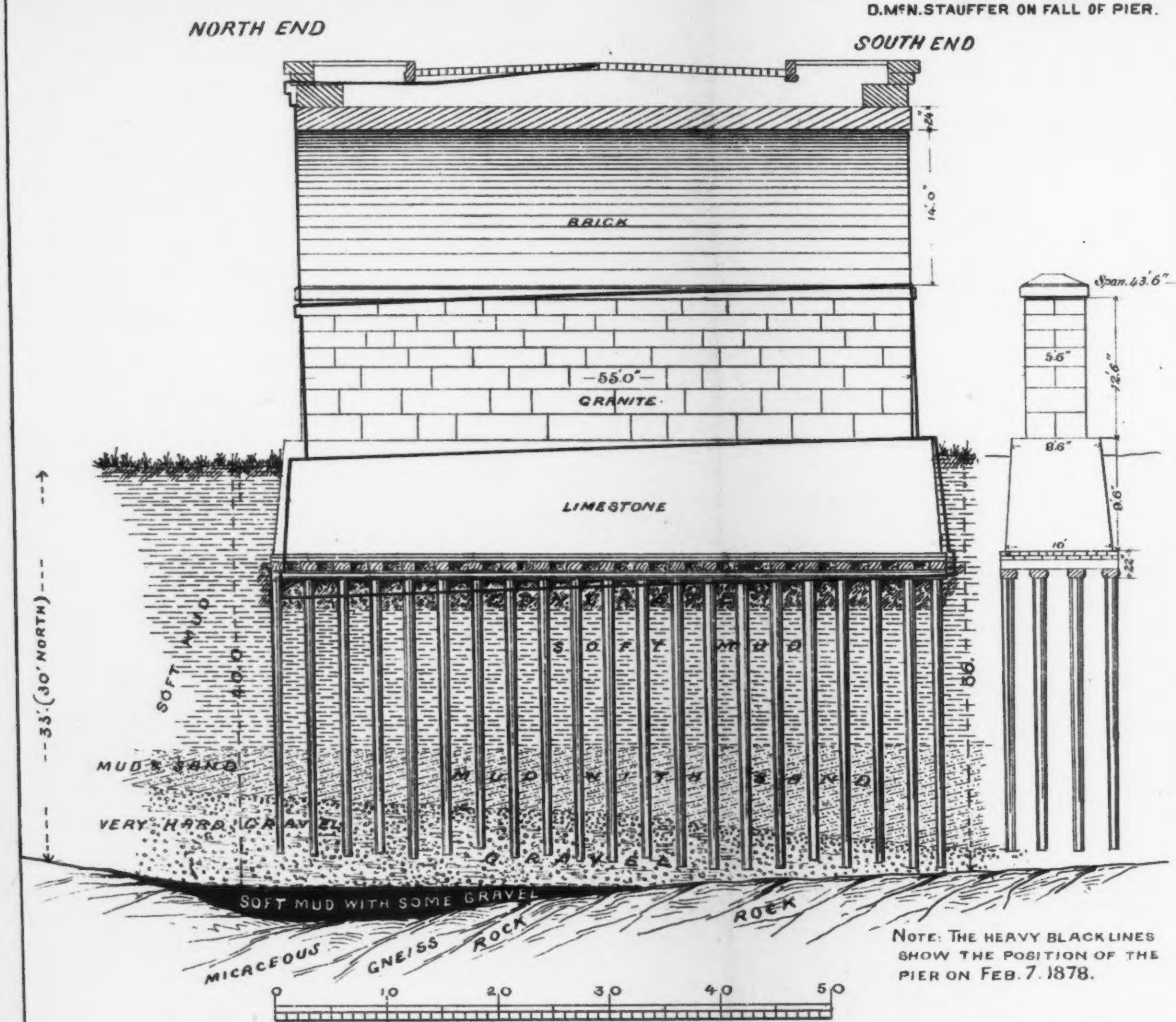
Fig. 4.

Fig. 4a.



SCALE FOR FIG. 4a.

PLATE XXXIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXXI
D. McN. STAUFFER ON FALL OF PIER.

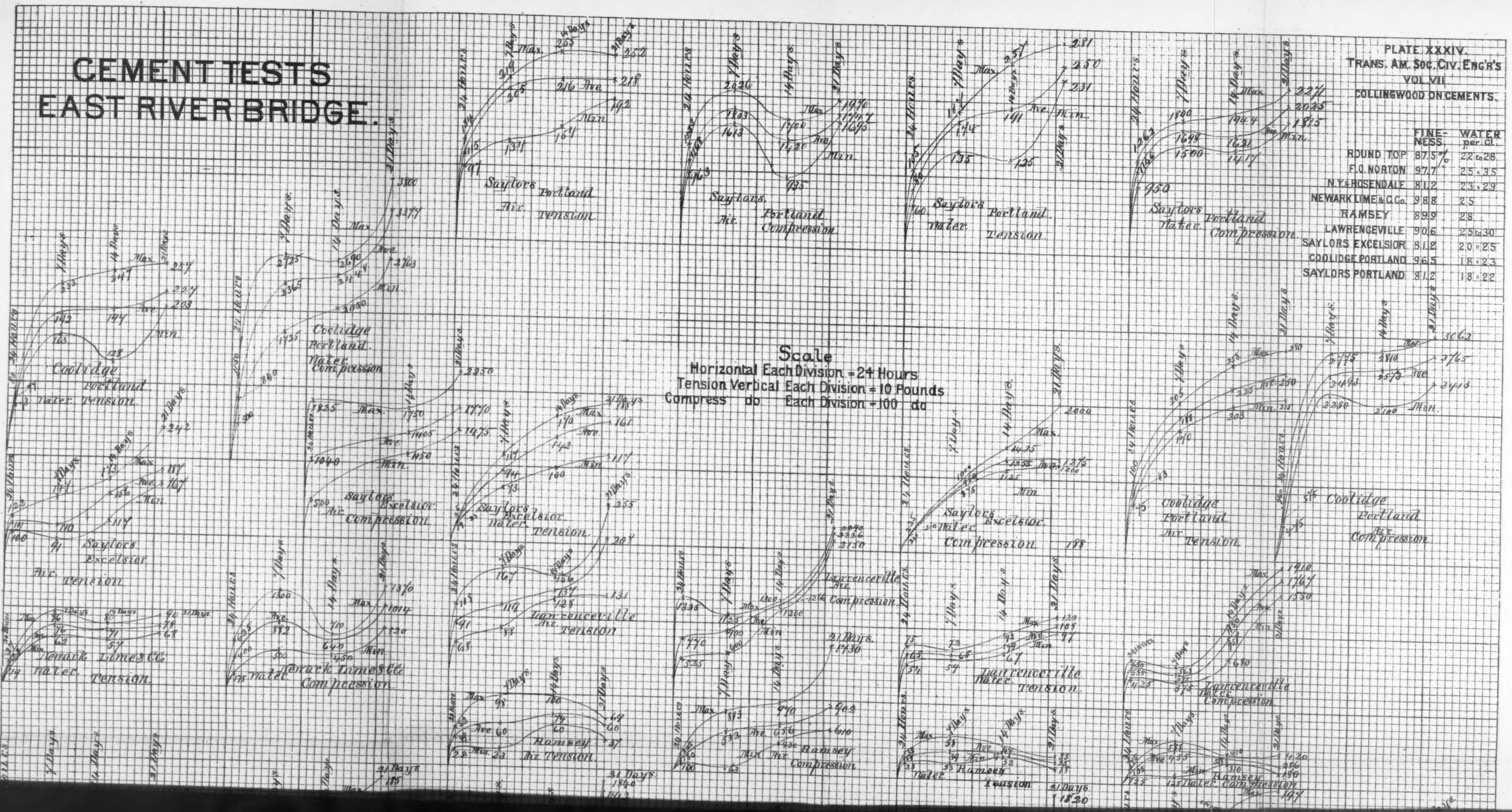


NOTE: THE HEAVY BLACK LINES SHOW THE POSITION OF THE PIER ON FEB. 7. 1878.

PIER NO: 2 SOUTH ST: BRIDGE

PHILADELPHIA PENNA:

CEMENT TESTS EAST RIVER BRIDGE.



	FINENESS	WATER per ct.
ROUND TOP	87.5 %	22 to 28
F. O. NORTON	97.7	25 " 35
N.Y. & ROSENDALE	81.2	23 " 29
NEWARK LIME & C. Co.	98.8	25
RAMSEY	89.9	28
LAWRENCEVILLE	90.6	25 to 30
SAYLORS EXCELSIOR	81.2	20 " 25
COOLIDGE PORTLAND	96.5	18 " 23
SAYLORS PORTLAND	81.2	18 " 22

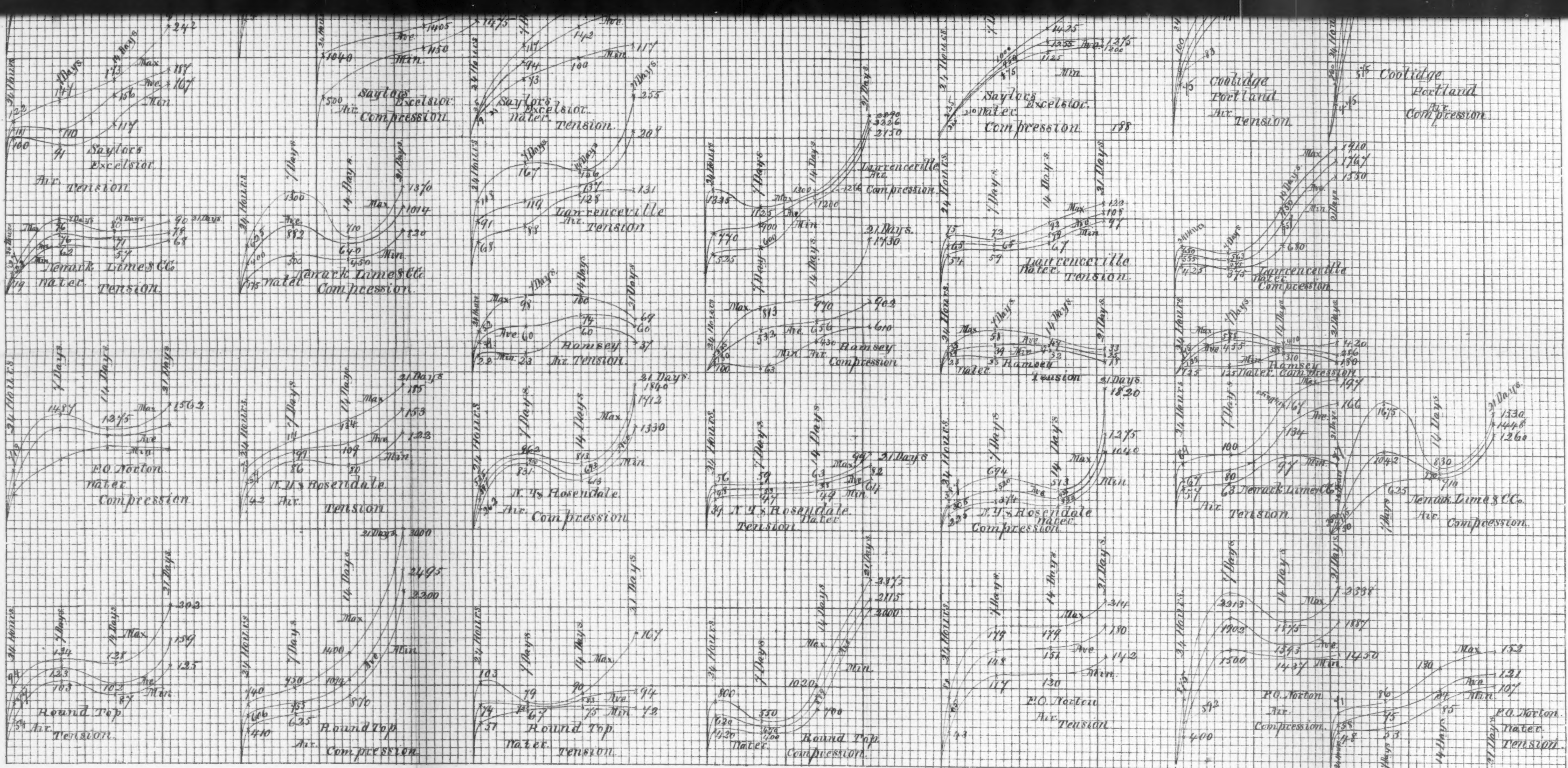
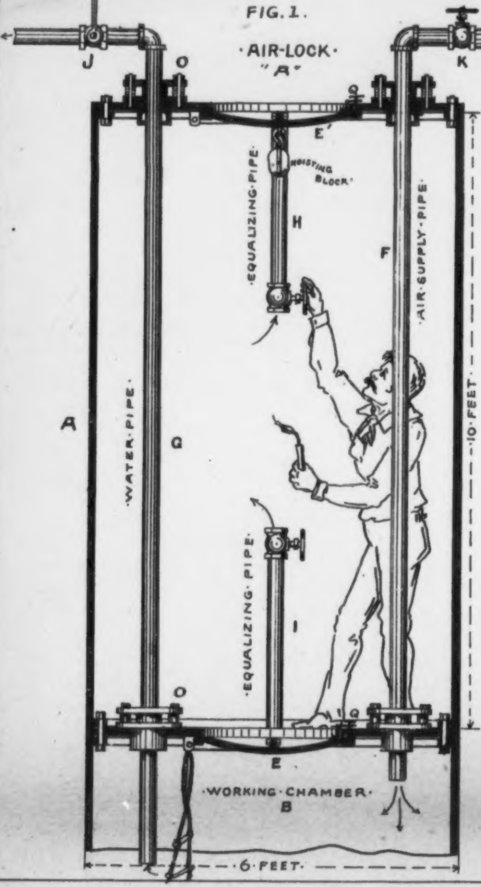
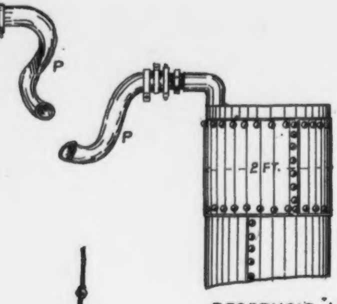

Saylors Excelsior Air Tension
Saylors Excelsior Air Compression
Saylors Excelsior Water Tension
Saylors Excelsior Water Compression
Coolidge Portland Air Tension
Coolidge Portland Air Compression
Newark Lime & C. Co. Water Tension
Newark Lime & C. Co. Water Compression
Lawrenceville Air Tension
Lawrenceville Air Compression
Lawrenceville Water Tension
Lawrenceville Water Compression
Ramsey Air Tension
Ramsey Compression
Ramsey Water Tension
Ramsey Water Compression
F.O. Norton Water Compression
N. Y. & Rosendale Air Tension
N. Y. & Rosendale Air Compression
N. Y. & Rosendale Water Tension
N. Y. & Rosendale Water Compression
Newark Lime & C. Co. Air Tension
Newark Lime & C. Co. Air Compression
Round Top Air Tension
Round Top Air Compression
Round Top Water Tension
Round Top Water Compression
F.O. Norton Air Tension
F.O. Norton Air Compression
F.O. Norton Water Tension

FIG. 1.



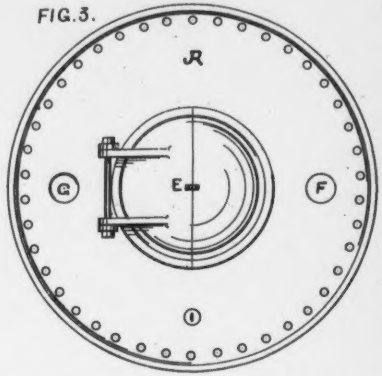


RESERVOIR-"L"

FIG. 2.

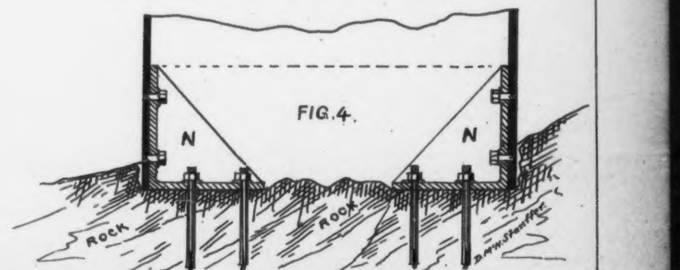
·DIAPHRAGM·

FIG. 3.



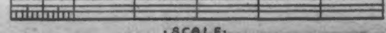
·BAG·FOR·HOISTING·
·OUT·MATERIAL·
·CONT'S·1½ CU. FEET·

FIG. 5.



·COLUMN·BRACKETS·

·PNEUMATIC·CYLINDERS·
·SOUTH·ST: BRIDGE·
·PHILADELPHIA·PA·

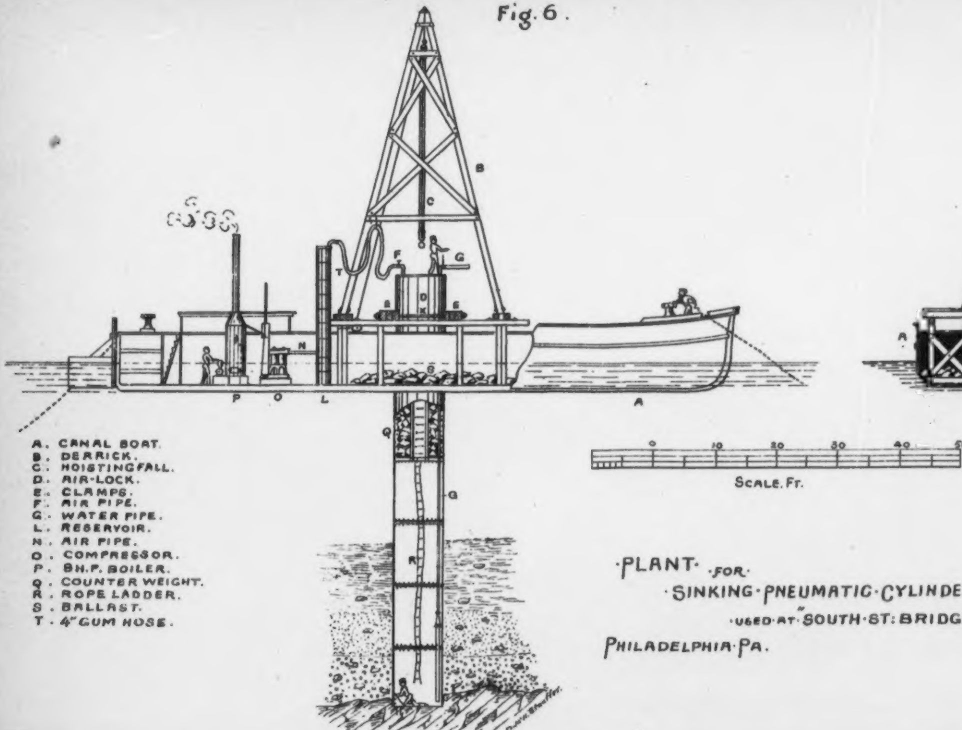


·SCALE·

PLATE XXXV.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII No. CLXXII.
D. McN. STAUFFER
PNEUMATIC·CYLINDERS.

PLATE XXXVI.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII Nº CLXXII.
D. McN. STAUFFER ON
PNEUMATIC·CYLINDERS.

Fig. 6.



A. CANAL BOAT.
B. DERRICK.
C. HOISTINGFALL.
D. AIR-LOCK.
E. CLAMPS.
F. AIR PIPE.
G. WATER PIPE.
L. RESERVOIR.
N. AIR PIPE.
O. COMPRESSOR.
P. 8H.P. BOILER.
Q. COUNTER WEIGHT.
R. ROPE LADDER.
S. BALLAST.
T. 4" GUM HOSE.

·PLANT· ·FOR·
·SINKING·PNEUMATIC·CYLINDERS·
·USED·AT·"SOUTH·ST: BRIDGE"
PHILADELPHIA·PA.

Fig. 7.

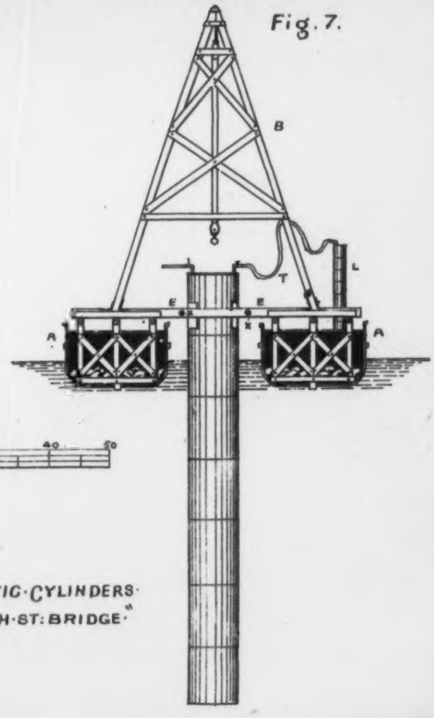
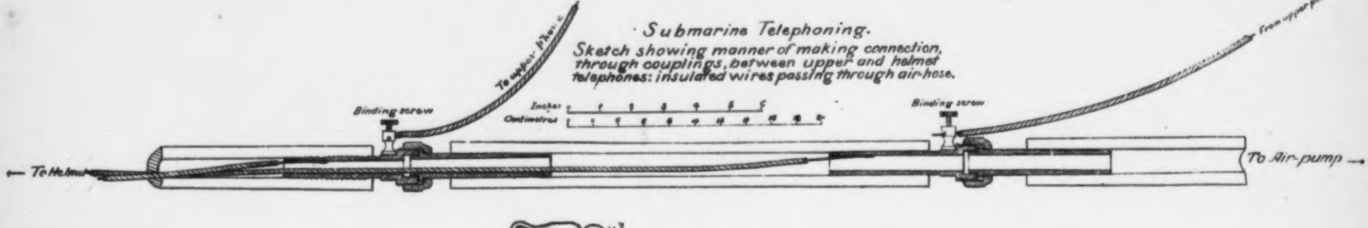
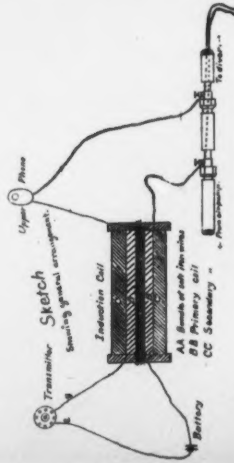


PLATE XXXVII.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No CLXXIII.
RAYMOND ON SUBMARINE
TELEPHONING.

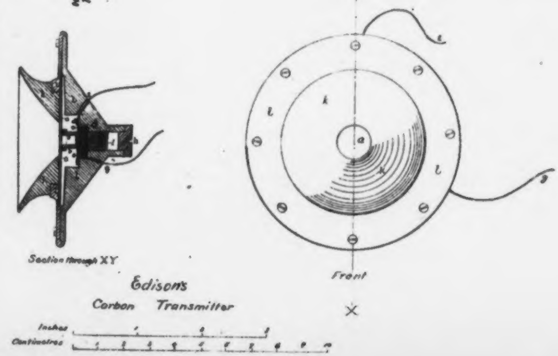
Submarine Telephoning.

Sketch showing manner of making connection, through couplings, between upper and helmet telephones: insulated wires passing through air-hose.





Sketch
Showing general arrangement.



Edison's
Carbon Transmitter


LVMINA NVMINA NOSTRA
ARS SVPERAT ET SVPEREST
PAIX
TRAVAIL
INNIXA PACI GALLIA FOVET ARTES
VERITAS
FORMA
EXPOSITION UNIVERSELLE DE 1878
LE JURY INTERNATIONAL DES RÉCOMPENSES
DÉCERNE
UN DIPLÔME D'HONNEUR
à la
SOCIÉTÉ AMÉRICAINE DES INGÉNIEURS CIVILS (États-Unis)
Groupe VI, Classe 66
LE SENATEUR COMMISSAIRE-GENERAL
LE MINISTRE DE L'AGRICULTURE ET DU COMMERCE
PARIS LE 21 OCTOBRE 1878
SCIENCES
BEAUX ARTS
RF

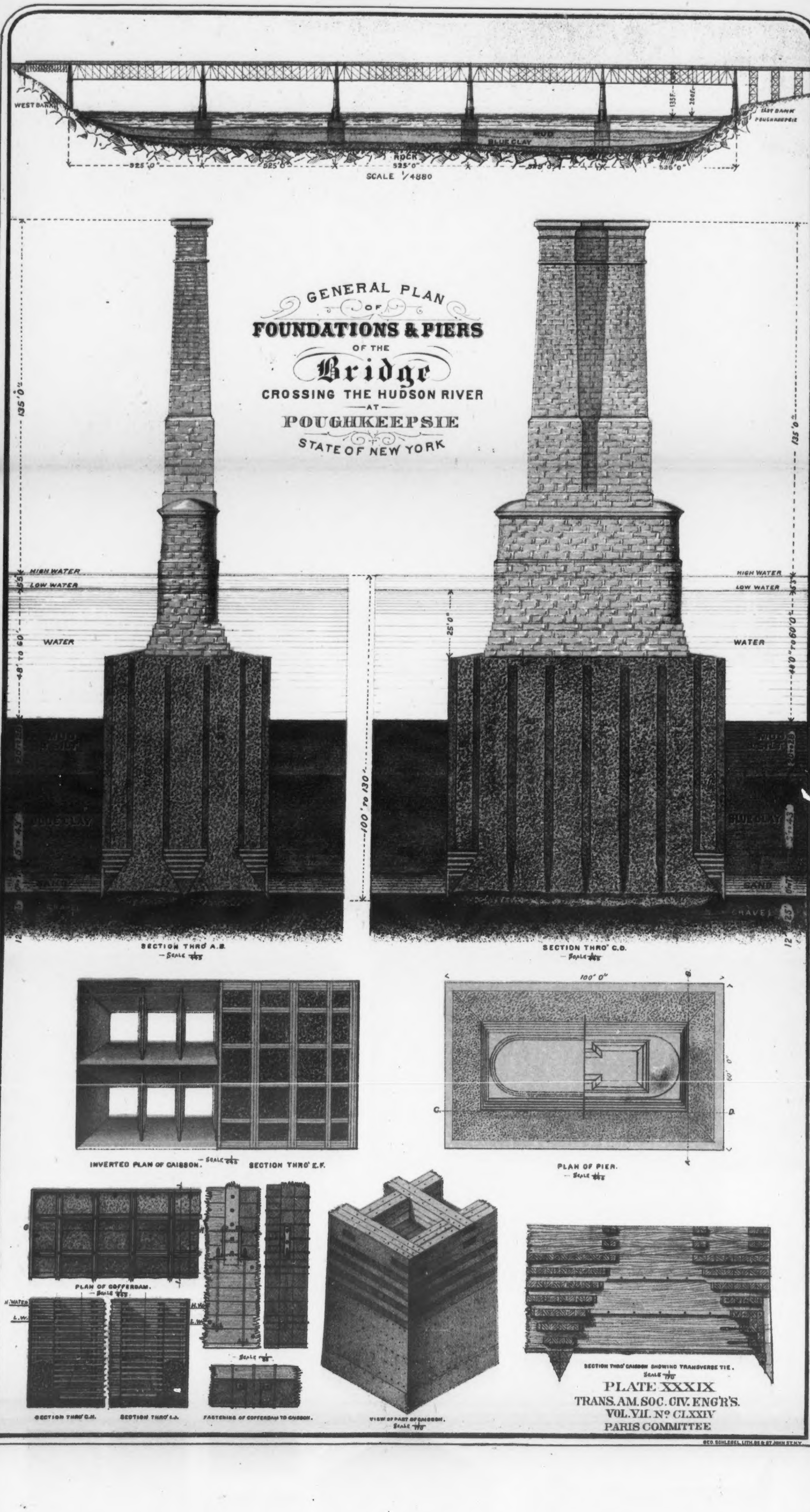
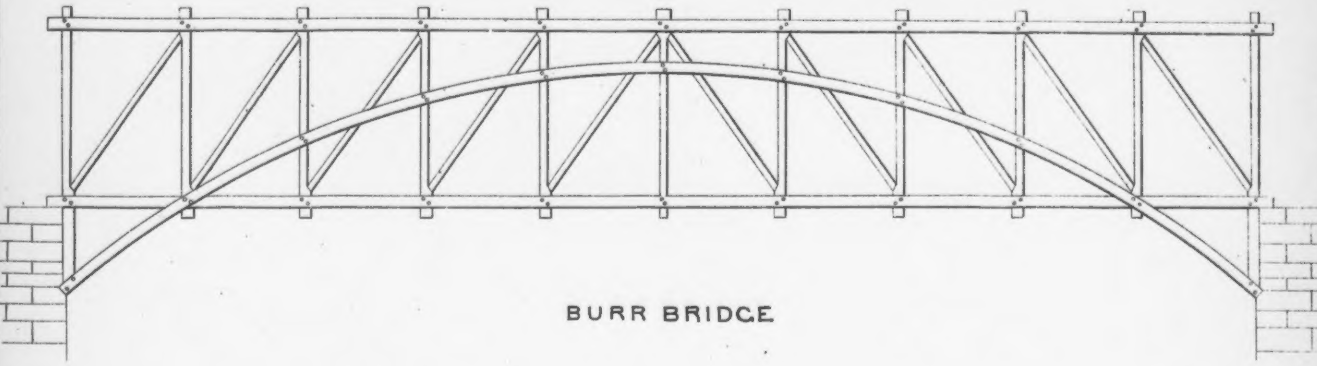
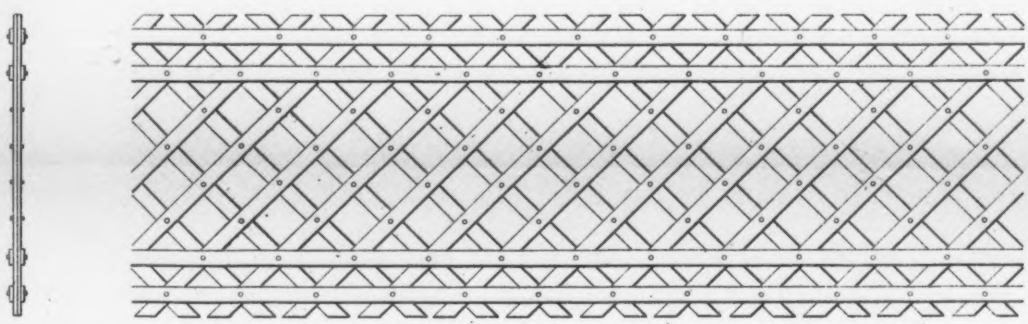


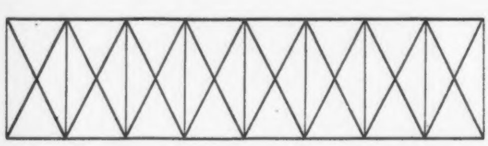
PLATE XXXIX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXXIV
PARIS COMMITTEE



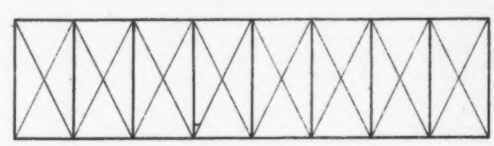
BURR BRIDGE



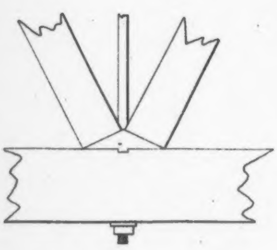
TOWN LATTICE



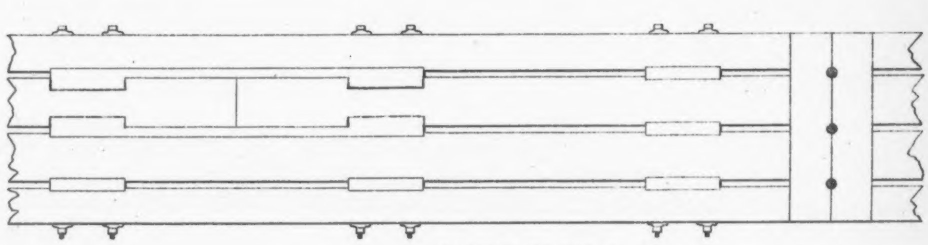
HOWE TRUSS



PRATT TRUSS



ANGLE BLOCK CONNECTION



PACKING OF CHORD

DETAILS OF HOWE TRUSS

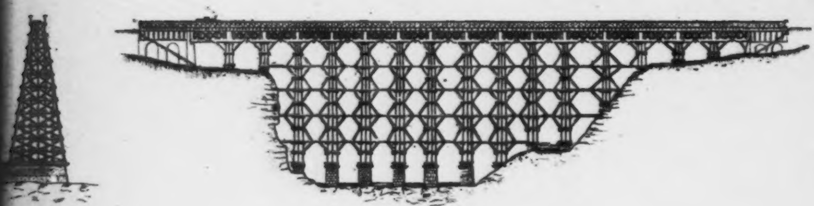
BOLLMAN TRUSS

FINK TRUSS

WHIPPLE TRUSS

POST TRUSS

PLATE XLI
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXIV.
PARIS COMMITTEE



Section.

1852.

PORTAGE VIADUCT

1875

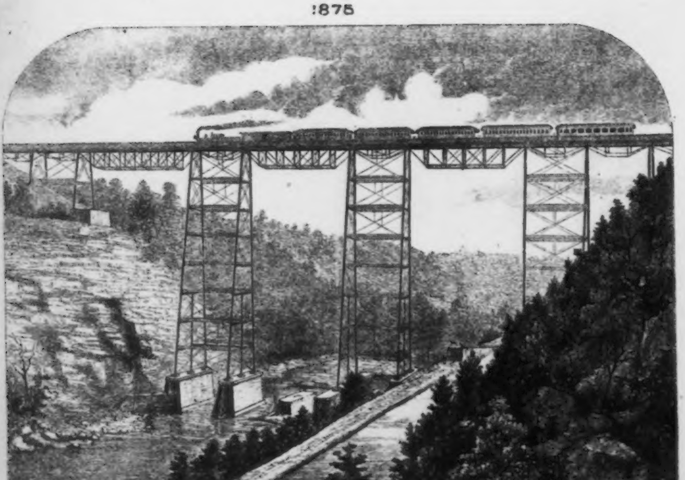
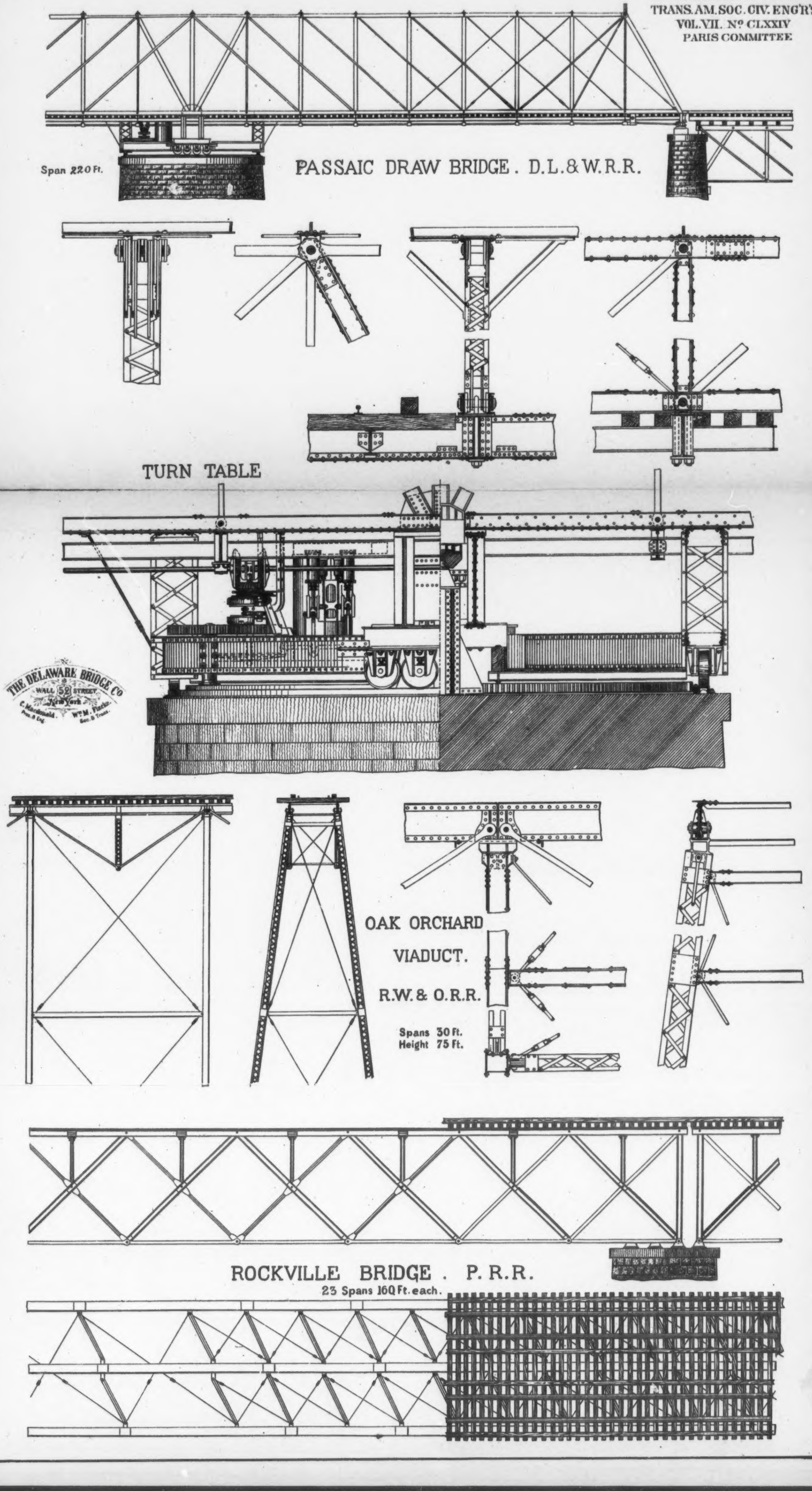
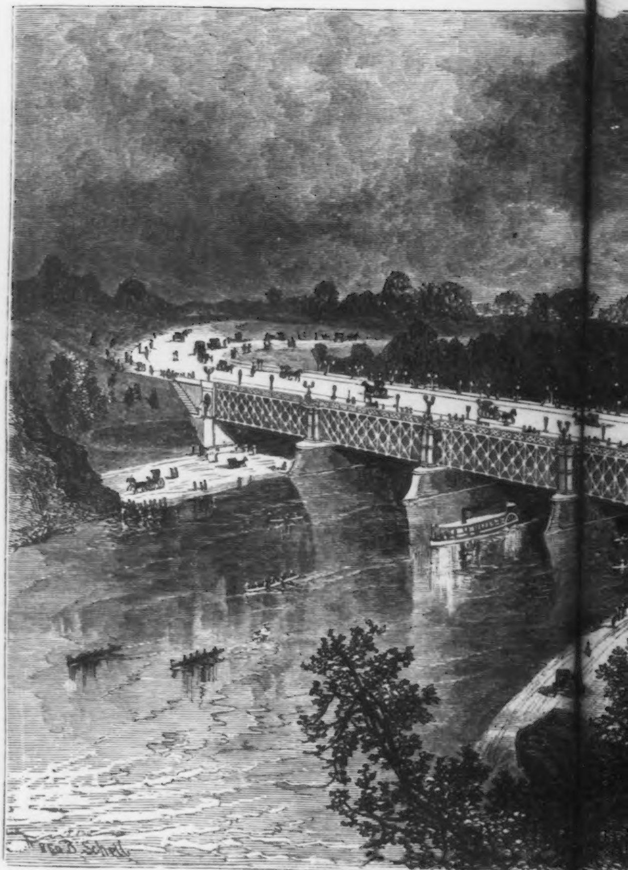


PLATE XLII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. Nº CLXXIV
PARIS COMMITTEE

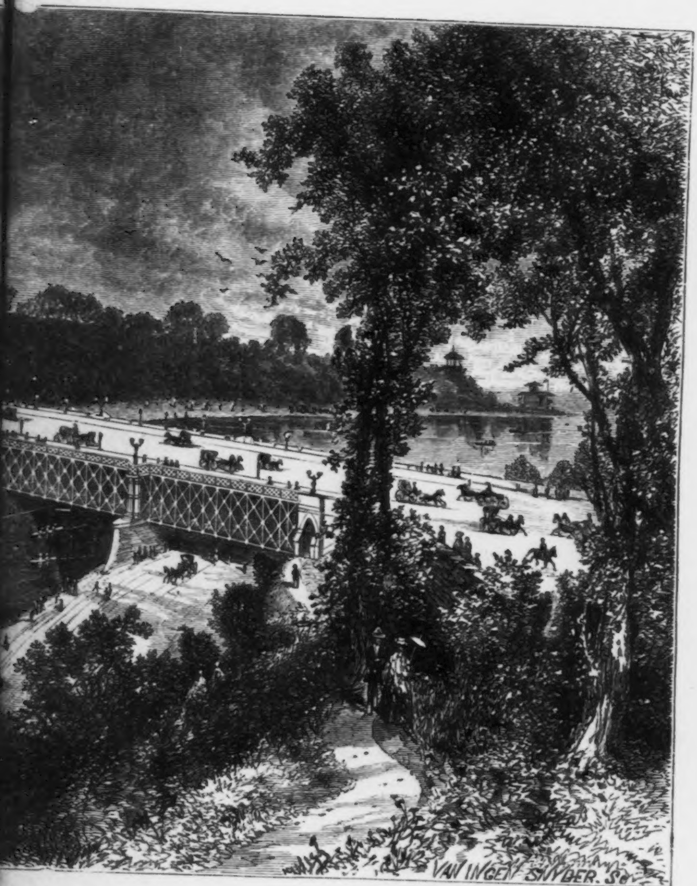


PL AT



GIRARD AVE

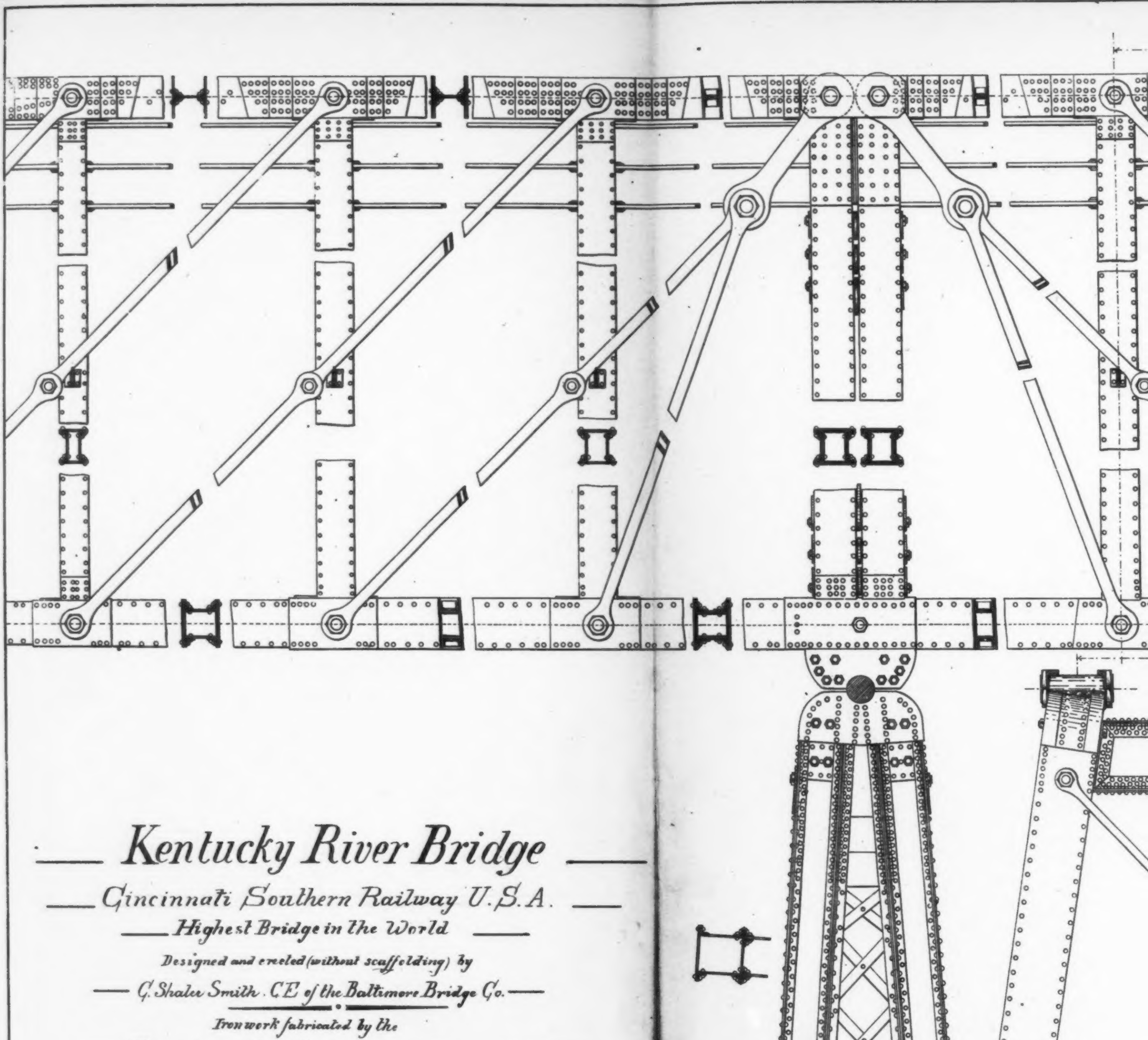
ATE XLIII.

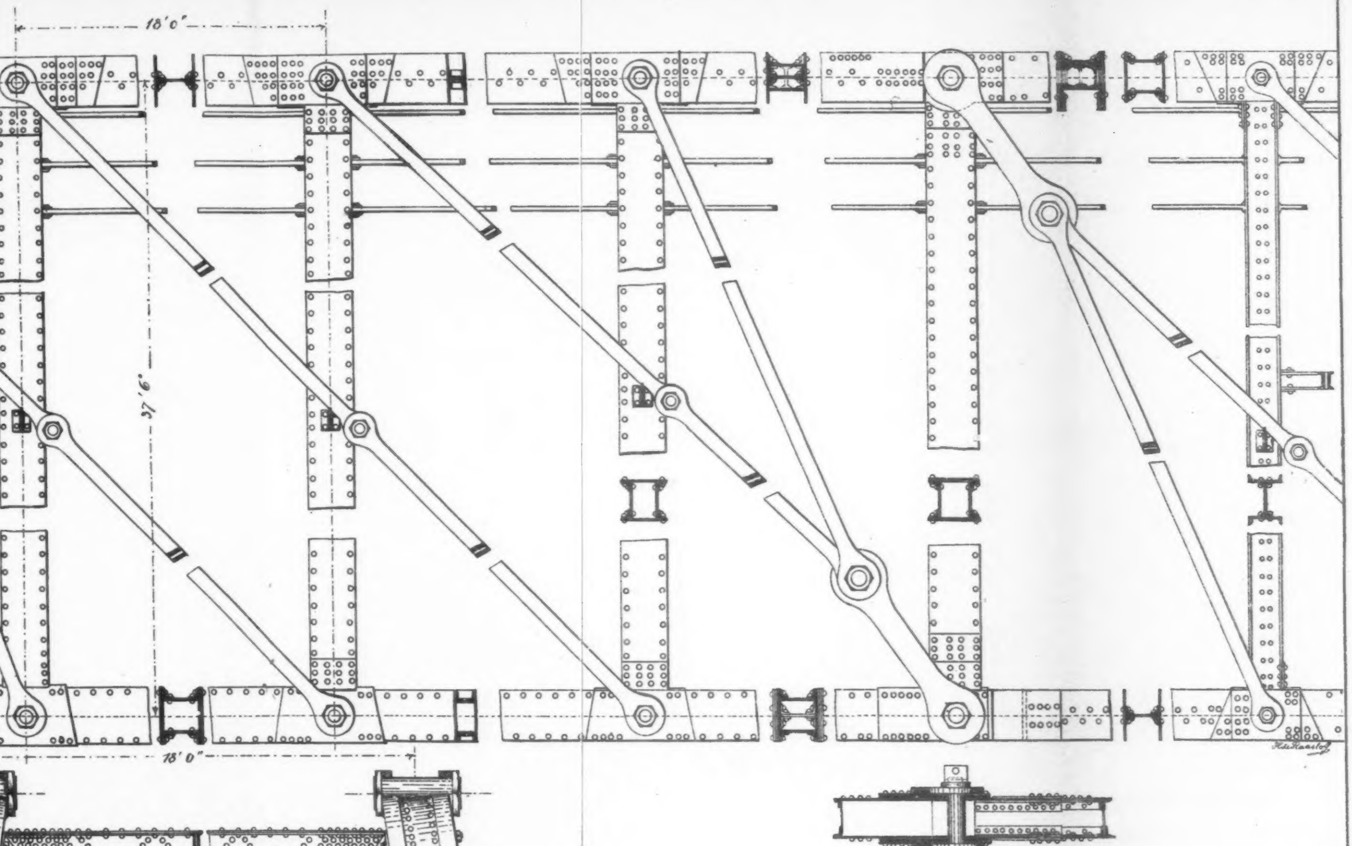


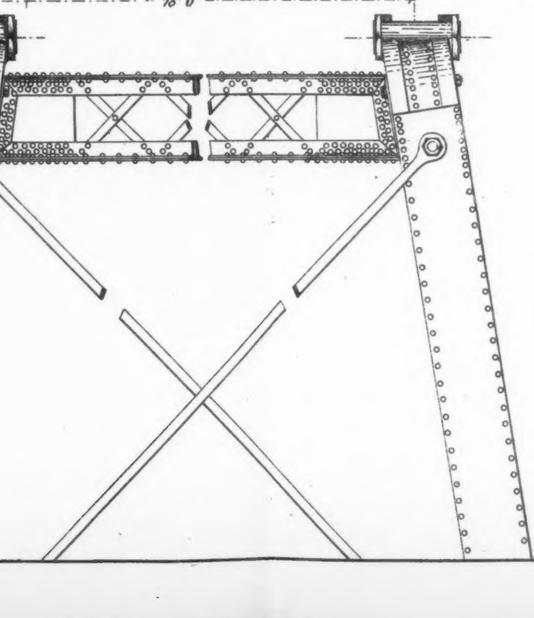
AVENUE BRIDGE.

LOUISVILLE

GEO. SCHLEGEL, LITH. 85 & 87 JOHN ST. N.Y.


Kentucky River Bridge
Cincinnati Southern Railway U.S.A.
Highest Bridge in the World
Designed and erected (without scaffolding) by
C. Shaler Smith. C.E. of the Baltimore Bridge Co.
Ironwork fabricated by the
Edge Moor Iron Co. of Wilmigton. Delaware. U.S.A.



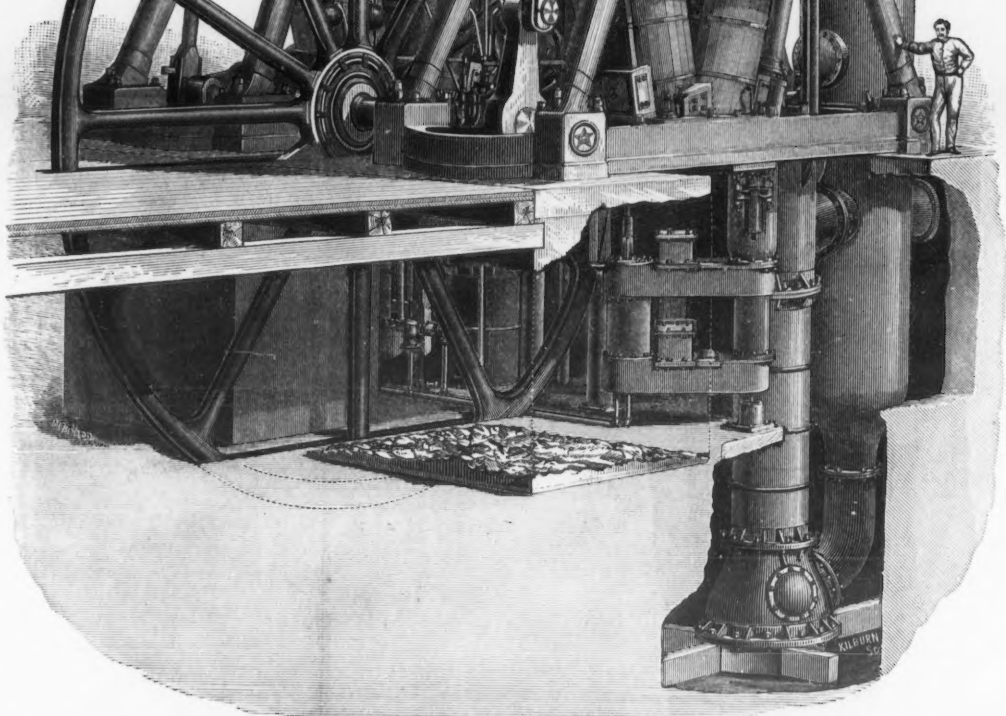


Dimensions and Quantities

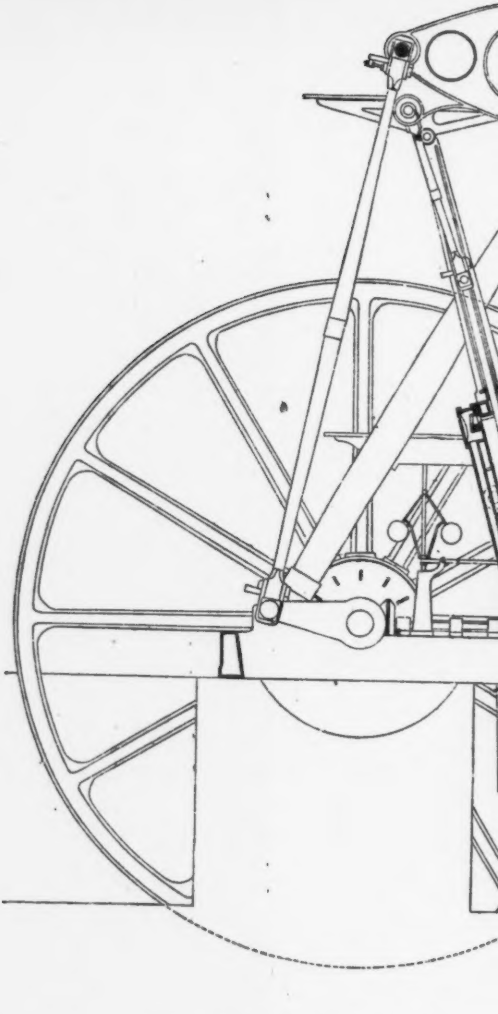
Length between Abutments	1138.00 feet.	Stone pier at base	119.5 x 42.0 feet
Length of each Span	375.00 "	Iron pier at base	71.5 x 28.0 "
Depth of Truss	37.50 "	Iron pier at Top	18.0 x 1.0 "
Width of Truss	18.00 "	Iron in Spans	2.355.379 lbs.
Height of Rail above low water	275.50 "	Iron in piers	798.901 "
Height of rail above River Bed	279.50 "	Cubic yards of masonry	12.935
Height of rail above Pier base	286.10 "	Cubic yards of foundation excavation	14.665
Total height of iron work	214.75 "	Flood rise of River	57 feet.
Total height of masonry	71.25 "		

PLATE XLV
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No. CLXXIV.
PARIS COMMITTEE

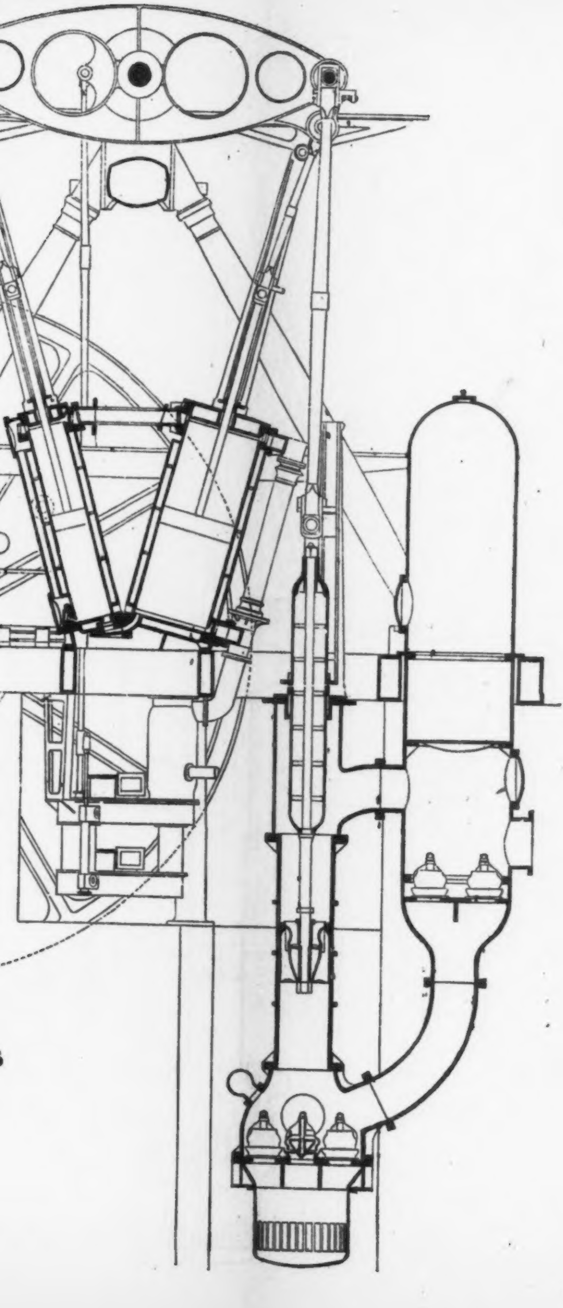
PLATE XLVIII.



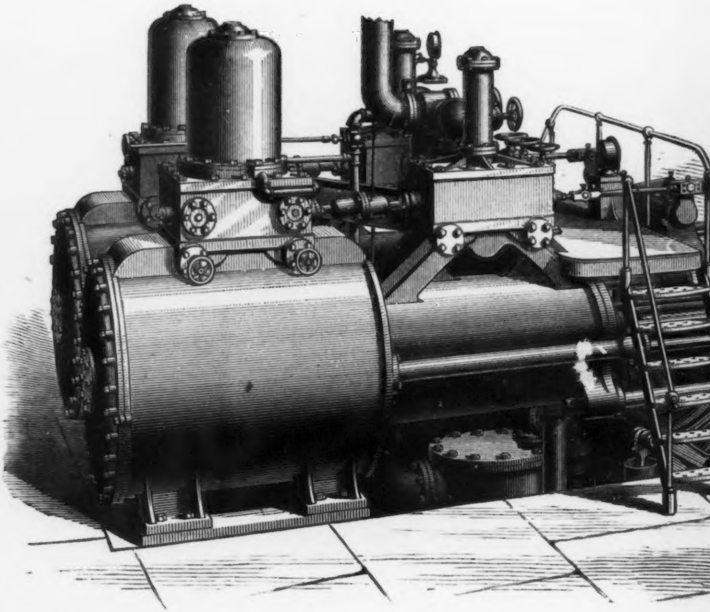
PUMPING ENGINE AT LAWRENCE, MASS.



LAWRENCE WATER WORKS
ENGINES A&B

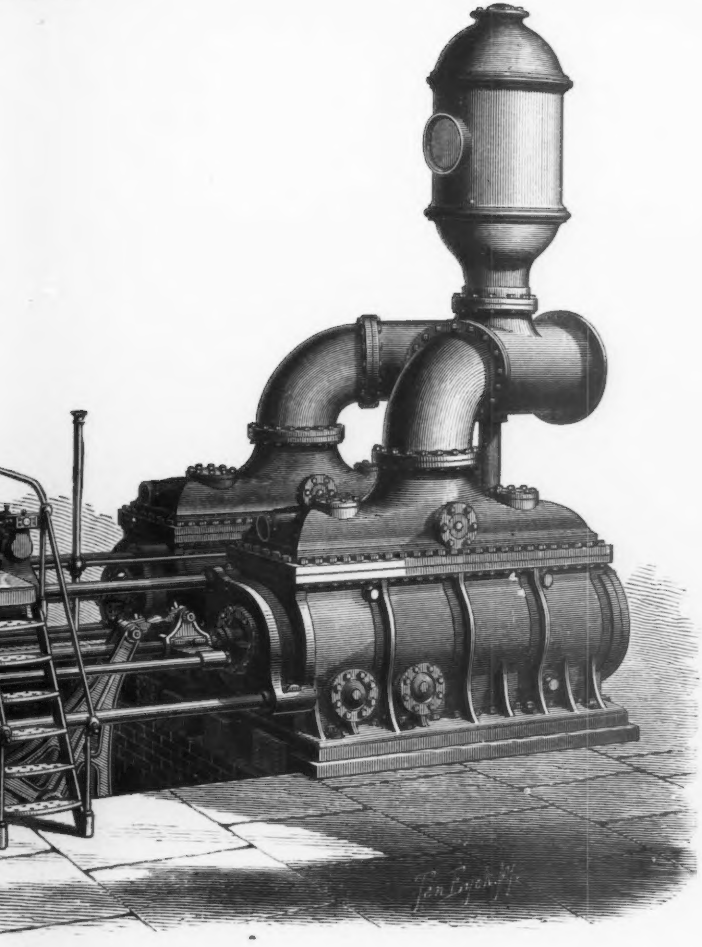


PLATE



WORTHINGTON DUPLEX

ATE L.



LEX PUMPING ENGINE.

PLATE LI
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. Nº CLXXIV
PARIS COMMITTEE

FULTON'S SKETCH
HIS FERRY SYSTEM

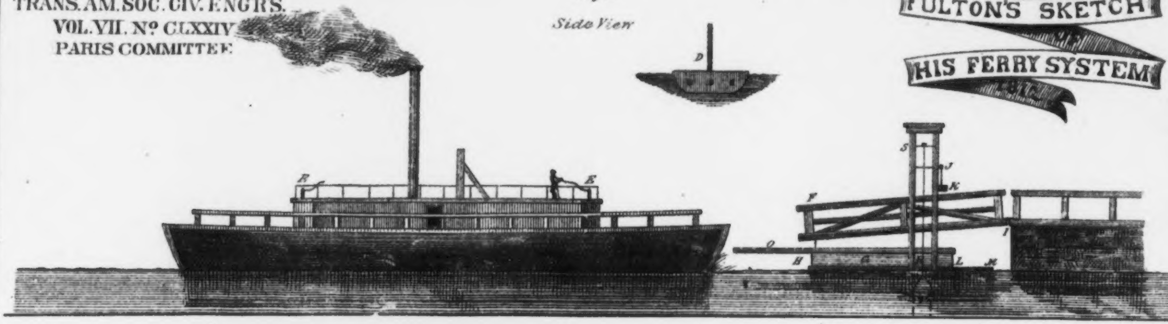


Fig. 1
Side View

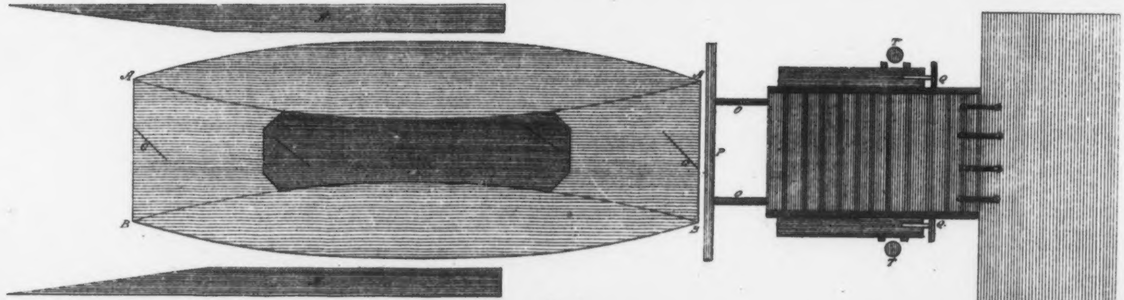


Fig. 2
Birds-eye View

PLATE LIII.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VII. No CLXXIV
PARIS COMMITTEE


ATLANTIC DREDGING CO.
361 FULTON ST BROOKLYN N.Y.
Nº6

CANAL CHESAPEAKE - OHIO.

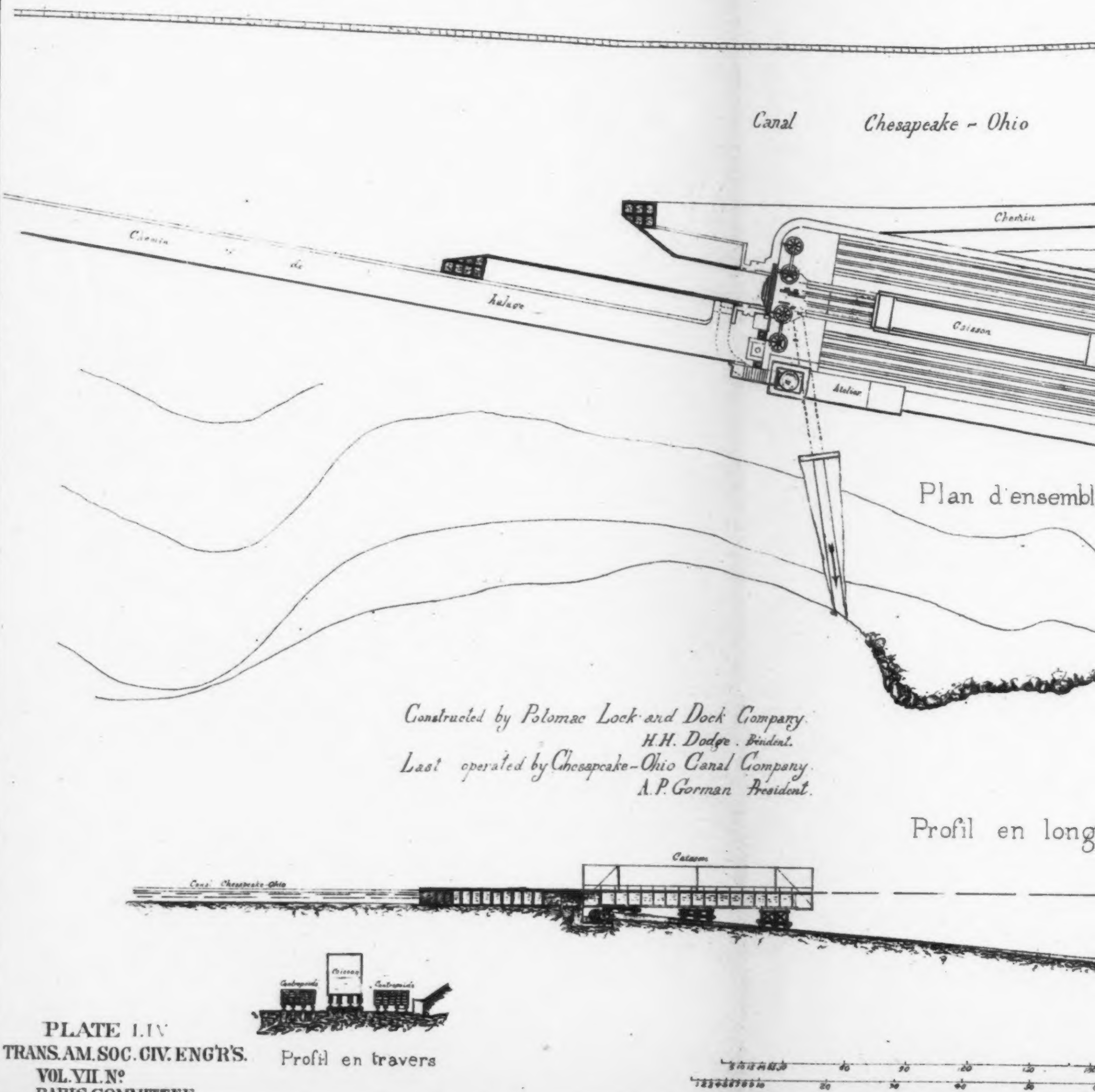


PLATE LIV

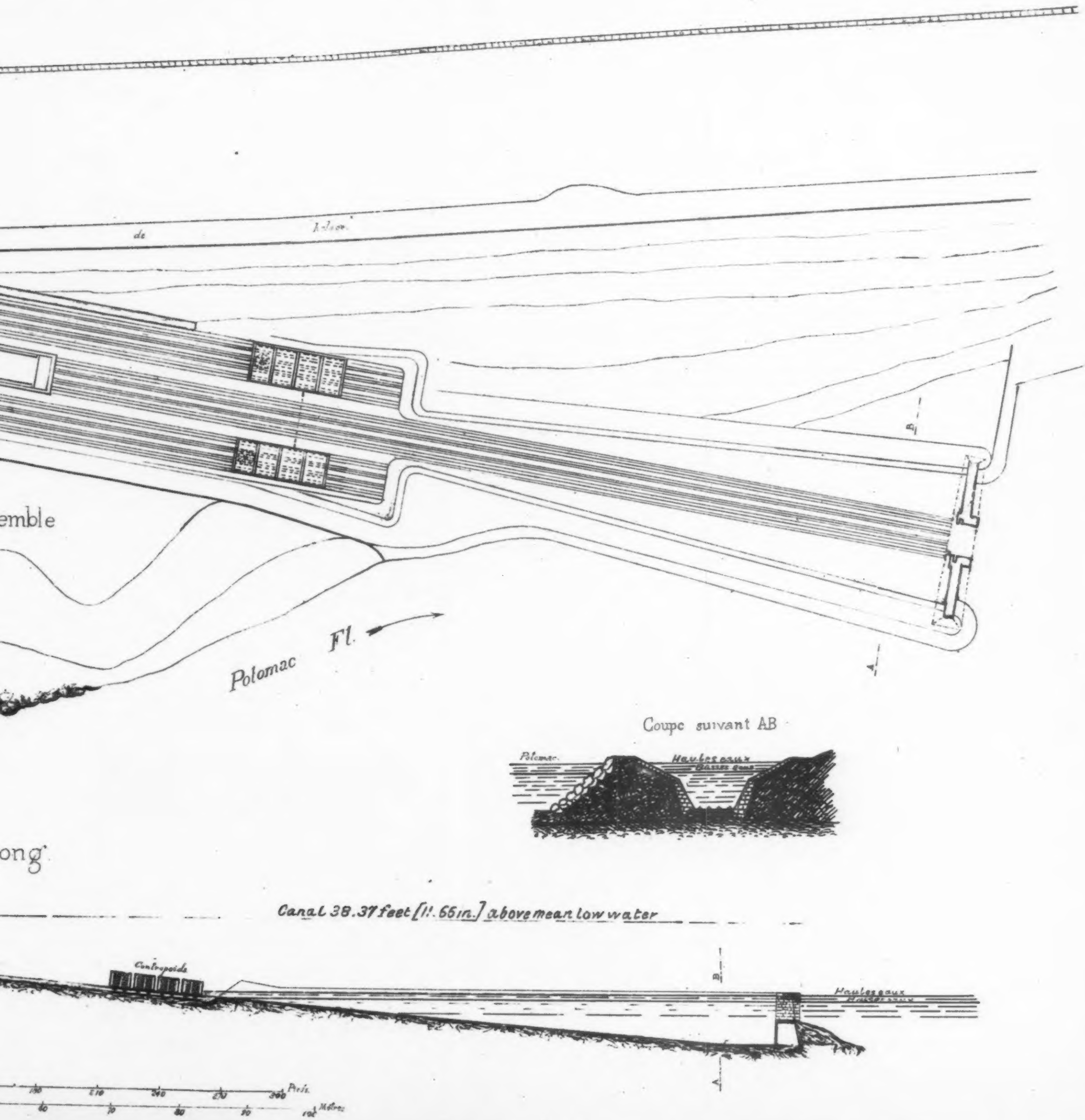
TRANS. AM. SOC. CIV. ENG'R'S.

VOL. VII. No.

PARIS COMMITTEE

ÉCLUSE A PLAN INCLINÉ

PRÈS WASINGTON _ ÉTATS - UNIS.




EAST RIVER BRIDGE.
SOCIETE AMERICAINE